* updated plan to address State Health design concerns for leach pad extension.

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ENGINEERING FEASIBILITY REPORT
NORTH LILY MINING COMPANY
TINTIC PROJECT

JOB NUMBER 19245-002-162

SEPTEMBER 1990

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DAMES & MOORE

File M

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INTRODUCTION

North Lily Mining Company (NLMC) has constructed a gold and silver heap leach extraction facility at their Tintic Project. The recovery process consists of a cyanide solution heap leach followed by a Merrill-Crowe extraction circuit for the secondary recovery of gold and silver. NLMC is now considering construction of additional heap leach pads at the site. Dames & Moore (D&M) has been authorized by NLMC to design the leach pad and surface diversion enhancements. Facility layouts have been determined in conjunction with NLMC.

The site is on land owned by the NLMC and is located approximately four miles southwest of Eureka, Utah (see drawing 1), adjacent to US highway 6. NLMC is a corporation with Grant A. Pinkerton, General Manager, the designated representative for their Tintic operation.

Originally NLMC constructed a heap leach pad, a process plant and solution ponds with Steffen Robertson and Kirsten (SRK) Inc. acting as consulting engineers. The leach pad was approximately 379,000 square feet (8.7 acres) in area. Subsequently the plant has undergone one expansion (1989), the addition of a heap pad directly south and adjacent to the existing pad. The 186,000 square feet (4.3 acres) expansion brought the leach pad area to the current 565,000 square foot (13 acres) size.

Dames & Moore (D&M), consultants for the previous addition, have been authorized by NLMC to design the currently proposed expansion. This expansion is proposed in three phases. Phase I would be built upon receipt of agency approvals and phases II and III as ore reserves are developed. Design and construction for each phase would be very similar to the original addition.

Phase I would be directly north and adjacent to the existing pad, with an area of 155,200 square feet (3.6 acres), bringing the total area to 720,200 square feet (16.6 acres). This is an increase of about 27% to the current area.

Phase II would be adjacent to and directly east of the existing pad, at the south end, with an area of 169,500 square feet (3.9 acres), adding 30% to the current area bringing the total to 889,700 square feet (20.5 acres).

Phase III would be east and adjacent to the existing pad and proposed phase I and also north and adjacent to phase II. The area for phase III is 146,000 square feet (3.4 acres), adding another 26% to the current area and bringing the total area to a maximum of 1,035,700 (23.9) square feet.

Phase I is on land entirely owned by NLMC. Approximately 74,600 square feet (1.7 acres) of phase II and approximately 79,900 square feet (1.8 acres) of phase III is on State land leased by NLMC.

This feasibility report is intended to provide the information required by the State of Utah, Department of Health, Division of Environmental Health, for heap leach projects under the Utah Administrative Code proposed rules R448-3-13.

SITE CONDITIONS

The area in the immediate vicinity of the site; including hydraulic features, roads, structures and facility components; is shown on drawing 1. Although surface water, groundwater and subsurface geological conditions have not changed significantly since the writing of the original SRK report, dated November 1987, a brief review follows for completeness of this document.

SUBSURFACE GEOLOGY

The site is located at the east central part of the basin and range physiographic province. The soils are alluvial and are within alluvial fans that extend westward from the East Tintic Mountains and are of the Pleistocene age. Some relatively recent alluvial deposits from flooding have cut into the older alluvium or have covered broad areas of bedrock where slopes flatten near the junction of stream channels (Morris, 1964b).

Several faults are located in the Cambrian rocks east of the site with much of the faults being covered by alluvial deposits. The Beck fault, Centennial fault, and the Grand Central fault are major fault in the proximity of the site.

The areas for the new pads were explored to evaluate surface and shallow subsurface conditions. A series of 11 test pits for phase I were excavated by NLMC and logged and sampled by D&M. These pits were excavated in August 1990 to depths ranging from 5 to 7 feet below the present ground surface. A series of 10 test pits for phases II and III were excavated and to depths of 5 to 8 feet and logged in September 1990. Location and logs of the test pits are shown on drawings 2 & 3.

The results of the backhoe pits explorations confirm that the soils in the proposed leach pad areas are similar to those previously explored and that the pad expansions are located on alluvial outwash fans. The upper soils consist of a sandy clayey silt topsoil with major roots and organic manner in the upper eight inches. Underlying these soils are predominantly layers of clayey silt to silty clay which are interbedded with occasional layers and lenses of silty fine to coarse sand and occasionally containing gravel. Some of the upper soils are partially cemented with calcite forming a relatively impermeable caliche layer. These caliche layers appear to be somewhat discontinuous as are the sand and granular layers. The soils are all generally firm with occasional layers of medium loose sand or gravel.

In general, alluvial deposits result in interbedded and intermixed layers of soil. Since most of the soil is silty and clayey in nature and because the granular soils are generally discontinuous, the vertical permeability of the overall layer is controlled in essence by the least permeable layers of silt and clay. Although some higher permeability soils ($\pm 10^{-3}$ cm/sec) materials might occur below the foundation of the proposed pad area, the overall permeability will be controlled by the silts and clays (10^{-6} to 10^{-8} cm/sec).

The previously explored borrow area has similar soil conditions although the soils tend to be more finely-grained because they are further downstream in the alluvial fan. Of the 14 test pits previously excavated in the proposed borrow area, an area containing the soils with the highest clay content, was selected for use as the borrow area. Soils in the area contain mostly very clayey silts and silty clays with only an occasional sand and gravel lens. Based on our evaluation of these soils, they are considered satisfactory for the general pad fill and the secondary liner material. The contractor will have to be somewhat selective during construction to avoid bringing the more permeable granular soils into the pad area.

SURFACE WATER

As described in the SRK report (pg 11-12) all of the streams in the area are ephemeral. The East Tintic mountains are east of the site and drainage is generally westward into the Tintic Valley toward Tanner Creek. Mammoth Gulch, which has a poorly defined channel, passes within about a half mile of the site and joins the joins the Eureka Creek drainage about one mile west of the site and eventually joins Tanner Creek. The only water sources identified near the site are the well on NLMC land, about 3/4 of a mile from the site, which supplies the site with water and a well at the Union Pacific Railroad's Tintic station about 2 miles away. There are no woodlands, springs, or irrigation ditches in the area.

GROUNDWATER

As previously established groundwater has not been observed at the site. This was established by a well drilled at the site to bedrock, which showed no water. At the producing NLMC well, approximately 3/4 of a mile west-northwest from the site and at a lower elevation, the water table at time of exploration was 440 feet below the ground surface at an elevation of about 5460 feet.

LABORATORY TESTS

Tests were previously performed to evaluate the strength and permeability characteristics of the foundation and borrow. The testing consisted of moisture and density tests of undisturbed samples, compaction tests, gradation tests, and specific gravity. In addition, new ore material was evaluated by a series of permeability and multi-stage consolidated, undrained triaxial compression tests (CU/PP). Tests showed that the friction angle for the heap material is 41 degrees which would be a slope of 1.15 horizontal to 1 vertical at repose (ie. safety factor of 1.0). Since all constructed slopes will be 2 to 1 we are well within limits for stable slopes. Permeability is within a range of 5.77×10^{-5} cm/sec to 3.56×10^{-4} cm/sec. A description of test procedures and data are presented in Appendix B of this report.

PLANS AND SPECIFICATIONS

Engineering drawings showing the details of the leach pad and other work involved in the expansion are included. The specifications provided in appendix A describe materials required for construction, quality assurance, testing, and compliance procedures for the work proposed.

PROCESS

The process will be unchanged from current operation. The heap material will be agglomerated using Portland cement in the agglomeration plant located east of the pads. A description of the existing facilities can be found in the SRK report (page 3).

ENGINEERING DESIGN

LEACH PAD DESIGN

Each of the new leach pads will be synthetically lined and contained within a perimeter berm. Dump material will be placed on the new pads to approximately uniform depths of up to 50 feet. Leach solution will be collected by a network of subdrains on top of each leach pad liner and will be routed into existing collection ditches. The solution in the ditches will flow by gravity to the pregnant solution pond.

FACILITIES LAYOUT AND DESIGN

During pad design an effort was made to: 1) minimize the disturbed acreage, 2) provide positive drainage around the facility, 3) minimize material quantities required for construction, i.e., balance cut-and-fill quantities insofar as possible, 4) provide flood protection for the berms for the facilities, 5) design liner systems to meet State requirements for protection of the environment.

The subgrade base for the leach pads will be recompacted existing clayey material and compacted clayey fill with a surface graded to the slopes and elevations shown on the drawings. If the exposed excavated surface of the base pad is unsuitable material, a six inch layer of material having a permeability no greater than 10^{-6} cm/sec will be spread, graded and compacted prior to the placement of the detection system. Thus, the entire subgrade for the pad will consist of material meeting a 10^{-6} cm/sec permeability requirement and will be uniformly graded. Cuts and fills on the order of two to three feet will be required to achieve this final subgrade base.

A minimum two-foot high perimeter berm is provided around each edge of the pads. Exposed areas will be covered with 40-mil ultraviolet (U.V.) resistent PVC liner material. In collection ditch areas the 40 mil liner will over lay a geonet and 30 mil pvc liner. The geonet will provide a leak detection collection system for the collection ditch areas. The covered portions of the pad will use a 30-mil PVC liner material. The grading of the pads, leak detection arrangement and drainage plans are shown in the drawings.

STORM DIVERSION

The maximum storm runoff from the small 6.7-acre area directly east of the pads has been estimated at approximately 9 cfs. A V-shaped diversion channel was designed to handle this flow with the water approximately one-foot deep and a slope of approximately 0.1 percent. Storm water will be diverted around the pads in a ditch of similar size to the existing ditch and will carry the discharge around the facility and discharge it onto the natural terrain (see Drawings 4 & 5).

LEAK DETECTION SYSTEM

Immediately overlying the graded subgrade of each pad, a leak detection system will be constructed (see Drawings 4 & 5). It will consist of a series of one-inch diameter perforated pipes which will be connected to a series of one-inch solid manifold pipes, which will carry the water to a series of riser pipes. The riser pipes will be monitored to detect any leakage into the detection system. The pipes will be overlain by four inches of clean granular sand and gravel which is in turn overlain by a geofabric to prevent clay liner material from infiltrating into the detection sand and gravel.

The riser pipes will be located at outer edges of the pads. Three of the existing sumps will be buried within the heaps. The buried sumps will have four-inch PVC pipes extending to outer edges of the pads from which they may be monitored with electronic sensors. The sensors are described in the specifications and manufactures literature has been included as appendix C. One inch diameter poly pipe will be installed within the PVC extension pipes which with a portable pump will provide a means of removing any detected solution.

The leak detection system will be covered by a secondary liner consisting of a 12-inch layer of clay (with a laboratory permeability no greater than 10^{-7} cm/sec) compacted to 95 percent of the maximum dry density as determined by ASTM Designation 698-A, Method of Compaction. The primary liner will consist of a 30-mil PVC synthetic liner under the ore heaps (40-mil UV resistent PVC where exposed around the edges and berm areas and 40-mil/geonet/30-mil in collection areas).

COLLECTION SYSTEM

For the Tintic site NLMC chooses to use a primary and a secondary leachate collection system to drain solution from the heaps. The secondary collection system (drawing 4 & 5) will consist of a series of 3 inch or larger perforated pipes connected to six-inch or larger diameter manifolds. These pipes will be placed at six feet center-to-center, or greater. A layer of protective material three feet thick will be placed over the pipes and primary liner to prevent damage to the liner. This protective cover will consist of tailings from the existing heap, which will be pushed over onto the new area and placed by hand over the pipes.

A primary collection system is planned above the protective cover to provide proper collection of leachate and minimize buildup of hydrostatic heads on the liner or within the ore pile itself. This primary collection system will consist of three-inch diameter pipes placed 6 feet center-to-center.

The overall system is designed to handle a discharge rate of up to 275 gallons per minute of leachate on the pond as well as storm runoff.

POND SIZING

Storm water falling on the heap leach pad and pond areas will be stored in the existing pregnant pond, barren pond and overflow pond system. These ponds have been designed and sized to meet the following criteria:

1. Normal working inventories;

2. One-hundred percent of a 24-hour heap draindown; and

3. Combined runoff from the pad and process area and direct precipitation on the ponds for a 100-year, 24-hour storm plus an average annual snowmelt.

A redundant pumping system with backup power generator has been provided for operation in case of a failure of the primary system. This effectively addresses requirement 2 and eliminates the need to design ponds for pad draindown.

The precipitation-frequencies summary for a 100-year return period shows that a 24-hour duration, 100-year storm would produce a total precipitation of 2.80 inches. An average annual snowmelt of 0.75 inches (the equivalent of 7.5 inches of snow) has been calculated. The maximum total plant flow is 275 gpm, which is less than the flow used in previous designs, but is all that the plant is capable of supplying. Calculations were performed to evaluate existing pond storage capacity for runoff storage when the new pad areas are included.

The volume available for storage within the three ponds currently includes approximately 0.750 million gallons in the pregnant pond, 0.793 gallons in the barren pond and 1.464 million gallons in the overflow pond, resulting in a combined capacity of 3.007 million gallons. These values do not include the eighteen-inch freeboard which could provide additional emergency storage. During normal operating periods both the pregnant pond and barren pond contain leachate approximately three feet deep while the overflow pond contains no water. This normal inventory is 0.470 million gallons.

The combination of the 24 hour-100-year storm plus snowmelt was determined to be the worst case. The emergency flows for the worst case conditions are summarized below.

Emergency Flow
(million gallons)

	Storm	Snowmelt	Total
Existing Pads	1.232	0.330	1.562
W/Phase I	1.503	0.403	1.906
W/Phases I & II	1.799	0.482	2.281
W/Phases I, II & III	2.054	0.550	2.604

The factor of safety for emergency storage, calculated as emergency flow divided by total capacity less normal inventory, for each phase with and without pond expansion is given below.

Safety Factor

Existing Pads	1.62
W/Phase I	1.33
W/Phases I & II	1.11
W/Phases I, II & III	0.97

Suitable safety factors for design emergency storage are provide through the development of phase II. The factor of safety once phase III is developed, however, is less than one. The necessary design storage including phase III can be accommodated in the existing ponds if the minimum freeboard required is reduced to 9 inches.

RECLAMATION

The "topsoil" stockpile are identified on the drawings. Some of the topsoil materials may be used to construct the berms so that they will be readily available for reclamation purposes.

Reclamation of the heap leach area will consist of neutralizing the heaps, filling in the ponds, and creating contoured, naturally revegetated areas which blend unobtrusively into the surrounding gentle slopes of the leach site as discussed in the SRK report. Reclamation contours for the new area are shown on drawing 8.

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NORTH LILY MINING COMPANY

TINTIC PROJECT

TECHNICAL SPECIFICATIONS

FOR

LEACH PAD CONSTRUCTION

Prepared by

DAMES & MOORE
SALT LAKE CITY, UTAH

Job. No. 19245-002-162
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1.0 INTRODUCTION

1.1 GENERAL

The technical specifications provided herein outline the materials and earthwork specifications for the construction of the heap leach expansion pad at the Tintic Project.

The aforementioned structure shall be constructed to the lines and dimensions shown in the construction drawings, and shall comply with the technical specifications provided for these structures.

Although not specifically stated, all changes or revisions in the construction or design of these facilities arising for reasons such as, but not limited to, changed conditions, Contractor's alternative construction procedures, Contractor's proposed alternative design changes, or Contractor's proposed alternative materials are subject to the Engineer's approval prior to work being conducted on the item in question.

1.2 SCOPE OF WORK

The work outlined in these specifications is for constructing a heap leach pad and appurtenant structures. The work includes, but is not limited to:

a. Site clearing and stripping, including grubbing;

b. Construction of leach pad, solution collection channel, and perimeter berms;

c. Installation of synthetic liners, sand drains, and leak detection piping.

Work not covered by these specifications includes:

a. All electrical and mechanical work;

b. Fine grading in the plant site area; and

c. Any concrete work required on the project.

1.3 DEFINITIONS

The following definitions apply to the technical specifications:

a. "Owner" is defined as an authorized representative of North Lily Mining Company.

b. "Engineer" shall mean Dames & Moore, a registered U.S. Limited Partnership with principal place of business in Los Angeles, CA.

c. "Contractor" is defined as the party which has executed a contract agreement for the work with Owner.

d. "In-place material" is defined as soils obtained from within the construction area of a particular facility.

e. "Overburden" is defined as soils obtained from overburden stripping for the mine.

f. "Waste rock" is defined as rock obtained from the mine that is of insufficient grade for milling.

g. "Off-site material" is defined as material obtained from sources other than on-site.

h. All slopes are described in terms of horizontal distance: vertical distance.

i. All sieve sizes refer to U.S. Standard sieve sizes.

1.4 APPLICABLE CODES AND REGULATIONS

The work shall conform to applicable Federal, State, County, and local regulations. Test procedures shall conform to applicable ASTM standards, as documented in the edition of the standards in force at the start of work.

2.0 SPECIAL PROVISIONS

2.1 CONTRACTOR'S RESPONSIBILITY

The Contractor shall examine the technical specifications and construction drawings and be aware of all conditions at the site affecting execution of the Work. These conditions include:

a. Applicable safety and health regulations;

b. Transportation and access conditions;

c. Availability of utilities;

d. Subsoil conditions;

e. Location, availability, and condition of construction materials; and

f. Climate and construction conditions at the site.

2.2 MOBILIZATION

Upon receipt of Notice To Proceed, the Contractor shall furnish, mobilize, and install such temporary works, materials, equipment and construction plant as are necessary for the successful completion of the Work. The Contractor shall also operate and maintain such temporary works, equipment, and construction plant throughout the period of construction. All temporary works, such as sanitation facilities, shall fully comply with the applicable rules and regulations of the governing authorities.

The Contractor shall obtain all necessary permits and permissions to utilize public roads for mobilization, demobilization, and access to the site. Access to the site is available by using existing public roads.

2.3 QUALITY ASSURANCE OF WORK

The quality and acceptability of all construction activities in these specifications will be determined by the Owner and the Engineer while the work is in progress. All work done by the Contractor shall meet the approval of the Engineer, but the detailed manner and methods of doing work shall be the responsibility of the Contractor.

Any part of any item of work which is found not to comply with the specification requirements or which is improperly located or constructed will be removed and replaced to the satisfaction of the Engineer, at the Contractor's expense.

2.4 ENVIRONMENTAL REQUIREMENTS

The Contractor shall store materials, confine his equipment, and maintain construction operations within limits indicated by applicable laws, ordinances, permits, or as outlined by the Engineer. Care shall be exercised to avoid blocking roads or in any other way interferring with the Owner's operations, or presenting a hazard to Owner's personnel and equipment, or to the public.

The Contractor shall at all times keep the site neat, tidy, and free of waste materials or rubbish resulting from his work. Fuel, lubricating oils, and chemicals shall be stored and dispensed in such a manner as to prevent or contain spills and prevent said liquids from reaching local drainage courses or ground water.

2.5 DIVERSION AND CARE OF WATER

Depending upon the time of year in which the work under these specifications is done, the Contractor shall design, construct, and maintain all temporary diversion and protective works required to divert runoff around the work areas and to protect persons and property downstream of the work. The Contractor shall furnish, install, maintain, and operate all equipment required to keep excavations and other work areas free from water in order to construct the facilities as specified.

2.6 SUSPENSION AND RESUMPTION OF OPERATIONS

The Contractor shall suspend fill placing and foundation preparation operations whenever, in the opinion of the Engineer, conditions for such operations are unsatisfactory due to rain, wind, or any other reason.

Where operations have been suspended, the effects of the rain, wind, or other adverse conditions will be assessed by the Engineer before approval to resume construction is given. Equipment shall not be allowed to travel on fill materials until the fill has dried sufficiently to prevent excessive rutting and to allow the equipment to be operated satisfactorily. If such rutting does occur, the Contractor shall re-level, scarify, and recompact the material to whatever depth is required, and the re-levelling and scarifying shall be at the Contractor's expense.

2.7 PROTECTION AND MAINTENANCE

The Contractor shall maintain all fill placed in a condition satisfactory to the Engineer.

The Contractor shall take such steps as are necessary to avoid ponding of water on the fill or contamination of the fill by traffic or other causes, and he shall at all times keep the fill surface and slopes free from rubbish, rejected or unsuitable fill, or waste materials.

The Contractor shall take such steps as are necessary to prevent damage to the synthetic liners.

2.8 DEMOBILIZATION

Demobilization shall consist of removal of temporary structures and shaping, contouring, and grading to provide surfaces for permanent stabilization and reclamation as required by Owner.

The Contractor shall remove all trash, debris, and waste material from the site and properly dispose of said material. The Owner shall have the right to determine what is waste material or rubbish and the manner and place of disposal. All materials furnished for the execution of the Work and thereby purchases by the Owner will remain the property of the Owner.

The Contractor shall clean out all installations, and tear down and remove all temporary structures built by the Contractor. Any existing structures or installations shall be left in a condition at least as good as the condition prior to construction. The Contractor shall also grade the construction site to provide proper drainage, and give a sightly appearance.

The final condition of the construction site is subject to approval of the Owner.

3.0 SITE PREPARATION

3.1 CLEARING

Clearing shall be done in the entire area within the limits delineated in the construction drawings. Clearing may extend a maximum of 20 ft outside of the facilities limits.

Clearing shall consist of cutting brush to the ground level, and removing such material along with wood, rubbish, and any other vegetation.

The vegetative material, rubbish, and other materials removed during clearing and grubbing shall be removed from the cleared area and disposed of in the area shown on the Drawings.

3.2 STRIPPING

Stripping of the topsoil shall be done in all areas with topsoil or vegetation. It is the intent of the owner to stockpile as much topsoil as is practical for future use in reclamation. Existing topsoil stockpile areas shall be identified by the Owner, relocated and stripped completely.

The stripped materials shall be removed from the area and placed in the designated stockpile areas. Placement of stripped soils outside of designated areas shall not be done unless directed otherwise by the Owner or Engineer.

3.3 GRUBBING

Grubbing shall be done at the direction of the Engineer. It is anticipated to occur only over a limited area, depending upon the ground surface following clearing and stripping.

Grubbing shall generally consist of the removal of stumps, vegetation, and roots 1-inch diameter or larger from below the surface of the natural ground.

4.0 EXCAVATION

4.1 GENERAL

All excavations shall be made to the lines and grades shown in the construction Drawings. Any and all excavations beyond these limits except as directed by the Engineer, shall be at the expense of the Contractor.

All necessary precautions shall be taken to preserve the material below and beyond the lines of excavation in the soundest possible condition. Where required to complete the Work, all such excess excavation or overexcavation shall be refilled with approved materials and placed and compacted to the satisfaction of the Engineer.

Excavations shall be graded and properly maintained to provide adequate drainage at all times. Excavated materials not used as fill shall be placed in the designated area as shown in the Drawings. Work shall be suspended when the site is wet, muddy, or in any other conditions when the area cannot be properly maintained.

4.2 DRAINAGE DIVERSION DITCH

The drainage diversion ditch shall be excavated to the lines and grades shown in the construction Drawings. Suitable excavated materials shall be used as fill materials or placed in the designated areas as shown in the Drawings, or properly spread and contoured along side the trench so as to grade into the natural topography.

4.3 CUTS AND SLOPES

The Contractor shall inspect all temporary and permanent open-cut excavations on a regular basis for signs of instability. Should signs of instability be noted, the Contractor shall undertake remedial measures immedaitely and shall notify the Engineer as soon as possible. It will be the Contractor's responsibility to remove all loose materials from the excavated slopes and to maintain the slopes in a safe and stable condition at all times during the progress of the Work and during any temporary closure of the Work. Permanent cut slopes shall be left in clean, safe, and stable condition at the close of the Work. Reclamation of the cut slopes shall be in accordance with specifications as stated in governing contracts for environmental and reclamation work for which the Subcontractor is responsible for execution and completion of the Work.

5.0 FILL MATERIALS

5.1 GENERAL

Fill materials shall be obtained from the mandatory excavations and borrow areas as shown in the Drawings. All fill materials shall be approved as fill for the intended purpose prior to placement.

5.2 LEACH FACILITIES BERM AND GENERAL FILL

General fill and the material required to construct the perimeter berms around the leach pad area will come from the excavation of alluvial foundation materials. The fill material shall be no coarser than the following gradation:

U.S. Standard Sieve	Percent Passing By Weight
6-inch	100
3-inch	95-100
1-inch	90-100
No. 4	80-100
No. 8	68-90
No. 30	45-70
No. 100	15-50
No. 200	0-40

5.3 LEACH PAD FOUNDATION

The material for grading and preparing the leach process area foundation shall be by reworking in-place material or be obtained from the mandatory excavation of the leach pad cut areas. Compaction of this area shall produce a smooth surface free of coarse rock or protruding material. The upper 6" of the prepared foundation, when compacted, shall have a maximum permeability of 1×10^{-6} cm/sec.

5.4 LEAK DETECTION SYSTEM

At a minimum spacing of 20', along all 1" diameter perforated PVC leak detection pipes, detection pipe dams shall be constructed as shown in the drawings. The dams shall be built using geofabric as specified in Section 6.5 and soil as prepared for the leach pad foundation.

A leak detection system (LDS) shall be constructed above the prepared foundation. The LDS shall consist of a sand and gravel blanket surrounding a network of drain pipes. The LDS shall be constructed as shown in the Drawings. The sand and gravel blanket shall consist of minus 3-inch material having less than 5 percent passing the No. 200 sieve and a permeability greater than 1×10^{-3} cm/sec.

The minus No. 100 sieve material shall be non-plastic. The granular material shall be free of rubbish and organic/vegetative matter.

5.5 SECONDARY LINER

A secondary liner will be constructed over the LDS (Section 5.4). The material required to construct the secondary liner below the leach pad shall come from approved excavations and borrow areas within the project area. The material shall meet the following specifications:

U.S. Standard Sieve Size	Percent Passing By Weight
1-inch	100
3/4-inch	95-100
3/8-inch	80-100
No. 4	70-100
No. 8	60-100
No. 200	40-100

The compacted material shall have a maximum permeability of 1×10^{-7} cm/sec.

6.0 LINER MATERIALS

6.1 GENERAL

The Contractor shall comply with the manufactûrer's specifications concernng all aspects of shipping, storage, installation, seaming, and sealing of the liners. The liners shall be shipped to the site in cartons containing folded, prefabricated panels or rolls of the synthetic liner. The panels shall be unfolded or unrolled and spread on the site, and the edges between the panels shall be seamed.

It is the Contractor's responsibility to install the liner without punctures, rips, or faulty field seams. All rips, punctures, and faulty field seams shall be repaired to the satisfaction of the Quality Assurance Engineer. Approval of the liner foundation by the Quality Assurance Engineer does not relieve the Contractor of the responsibility to repair any damage to the liner.

The Contractor shall place synthetic liner materials on a prepared liner fill surface as specified in Section 8.0

6.2 PVC LINER

The primary liner for the leach pad shall be 30-mil PVC or equivalent. The material shall meet the minimum requirements as set forth in the National Science Foundation (NSF) Standard No. 54. The Contractor shall submit for approval the name of the manufacturer and supplier of the liner and the manufacturer's specification of liner properties prior to purchase of the liner.

The liner shall be placed on the prepared foundation and welded at the seams in the manner suggested by the manufacturer and to the satisfaction of the Engineer. Direct vehicular contact with any liner shall be avoided to prevent damage to the liner.

The liner shall be installed to the limits as shown in the Drawings. The liner shall be anchored as shown in the Drawings.

6.3 COLLECTION CHANNEL

In all collection channel areas, from the toe of the heap into the anchor channel, the 30 mil liner shall be overlain by a geonet drainage net (Sec. 6.4) and at least a 40 mil U.V. resistant PVC liner. The 40 mil liner/geonet/ 30 mil liner system shall be as shown in the drawings, forming a leak detection system for the channel, conducting any leachate leaked through the upper liner to a detection sump.

The liners shall be installed and anchored in the ditches as shown in the Drawings. All seams shall be made in accordance with the manufacturer's recommendations and are subject to approval by the Engineer.

6.4 GEONET

The geonet shall be Tensar DN-3, Gundle Gundnet, or approved equal and shall have a minimum transmissivity of 1 gallon per minute per lineal foot.

6.5 GEOFABRIC

Geofabric shall be installed between the detection system and the secondary liner as shown in the Drawings.

The geofabric shall be non-woven, generally conforming to the specifications for Phillips Supac 4NP or equal. The fabric shall be inert to commonly encountered chemicals, resistant to ultraviolet light exposure, have a minimum permeability parallel to the fabric of 10^{-3} cm/sec under the anticipated stress, and shall be a minimum of 40-mils thick.

Any seams or joints made in the geofabric during installation shall require a minimum overlap of fabric of six inches. No wire or staples shall be used to secure the fabric at a lap. Prior to placement of clay secondary liner over the geofabric, the installation of the geofabric shall be approved by the Engineer.

6.6 SPREADING

Each panel shall be removed from its packaging, unfolded or unrolled, and spread into place. Each panel shall be placed into the proper location without stretching of edges that are to be field seamed. When each panel is properly located, the panel shall be smoothed to remove wrinkles in the liner.

All field seams in flat or graded areas shall be overlapped with the upslope panel lying on top of the downslope panel. Field and factory seams or slopes shall be aligned perpendicular to the slope contours.

6.7 SEAMING

Field seaming shall be performed using a method recommended by the manufacturer for the liner material and acceptable to the Quality Assurance Engineer. Before seaming is performed, the liner surfaces to be seamed shall be free of dirt, dust, and foreign materials.

6.8 REPAIRS

Prior to the placement of additional material over the synthetic liner material or use of the completed facility, the Quality Assurance Engineer shall observe the liner installation.

All faulty seams, punctures, tears or damaged areas in the liner shall be repaired to the Quality Assurance Engineer's satisfaction by applying a patch over the damaged area. The patch shall be of the same material as that of the damaged area, and shall overlap the damaged area a minimum of 2 inches. The patch shall be seamed to the original liner according to the recommendations of the liner prefabricator.

6.9 LINER PROTECTION IN LEACH PAD AREA

The primary synthetic membrane liner shall be protected from punctures and rips by installation upon the properly-rolled and smoothed clay secondary liner, and by limiting access across the liner to foot traffic. Laborers shall be restricted to those wearing approved footware. Following the installation of the liner and until the protective cover is placed, the liner shall be sufficiently weighted with sand bags to prevent damage from the wind.

6.10 TESTING AND FIELD OBSERVATION

The Contractor shall provide the Quality Assurance Engineer with a copy of the manufacturer's quality control testing for each shipment or partial shipment of liner if the entire shipment is not covered by the testing. Such testing shall include data on the melt index (ASTM D-1238), density (ASTM D-1504), tensile and elongation (ASTM D-882), thickness (ASTM D-1593), and carbon black content (ASTM D-1603).

The test data shall be referenced to a shipment number. Upon placement, the Contractor shall indicate by a plan the exact location at which the liner shipment is installed.

The Contractor shall be responsible for providing his own quality control personnel and testing equipment. The Quality Assurance Engineer will perform his own testing independent of the Contractor's testing. At the end of each shift, the Contractor shall submit to the Quality Assurance Engineer a written notice indicating the areas of installation completed during that shift.

Quality control testing shall involve both nondestructive and destructive testing. The nondestructive testing shall determine "watertightness" of the seam, whereas the destructive testing shall be based on the ASTM D-882 test method.

A visual examination of all seams shall be performed. Any suspect areas, breaks, or holes in the weld shall be recorded and marked for repair.

In addition to or concurrent with the visual inspection, the Contractor shall test all seams with the use of vacuum box, air lance or other standard techniques. Details of the method of nondestructive seam testing to be adopted shall be submitted to the Quality Assurance Engineer for approval prior to its use. Any holes detected in the seam shall be recorded and marked for repair. All repaired areas shall be retested upon completion of the repair.

6.11 PIPELINES

6.11.1 General

All pipe used for conveying solutions between the plant site and other facilities shall be sized as shown in the applicable drawings. The alignment and grade of the pipe shall be as shown in the Drawings.

6.11.2 Leak Detection Pipeline

The leak detection pipe in the leak detection system under the heap leach pad shall be one-inch I.D. Schedule 40 PVC or approved equivalent. The pipes shall be perforated with a maximum slot size of 1/32 inch and a minimum open area of 0.5 sq inch per ft of pipe except for the exposed portion of the riser pipes which will be solid. The riser pipe from the sump shall be a four-inch diameter pipe, Schedule 40 PVC or equivalent.

The extensions for the existing leak detection system shall be four-inch O.D. Schedule 40 PVC or approved equal. Elbows shall be four-inch O.D., Schedule 40 PVC or approved equal.

The detection pipe shall be placed on top of the prepared subgrade. Details of the pipe installation are shown in the construction Drawings. The extension pipe shall be placed in the liner protective cover material as shown in the construction drawings. All connections made shall be solvent welded according to manufacturer's recommendations and to the satisfaction of the Engineer.

7.0 LEAK DETECTION SYSTEM

A remote leak detection monitoring system capable of measuring 1" of solution shall be provided. The system shall include sensors for three sumps wired to a control panel with an indicator light for each sump, an audible alarm and reset button. An alarm test shall also be provided. The sensors shall be Warrick 3W-2, 303 stainless steel, electrodes or other approved sensor.

8.0 FOUNDATION PREPARATION

8.1 FILL AREAS

In areas where fill is to be placed, the foundation shall be prepared following stripping as follows; wet and recompact the upper 8 to 12 inches of in-situ material to the required density.

8.2 LEAK DETECTION FOUNDATION

The base foundation for the leak detection system under the secondary liner shall be graded to the dimensions shown in the Drawings. The prepared surface shall be a firm base free of loose material. The foundation material at the base of the leak detection system shall have a maximum permeability of 1×10^{-6} cm/sec. The minimum thickness of this layer shall be 6 inches.

The foundation of the leak detection system shall be graded to the dimension and elevation shown on the Drawings. The composite slope shall be such that it is free of depressions and has positive drainage towards the riser pipes.

8.3 SECONDARY LINER SURFACE

The secondary liner surface shall be rolled smooth with a smooth drum roller and shall be compatible with the manufacturer's recommendations. The foundation preparation is subject to the approval by the Engineer prior to placement of the synthetic liner.

9.0 FILL PLACEMENT

Fill materials shall be placed to the lines and grades shown in the Drawings. Fill slopes shall not exceed 2H:1V.

9.1 GENERAL

No materials shall be placed until the foundation and subgrade preparations have been completed as specified and approved by the Engineer. The procedures for the construction of the fills shall be discussed with and approved by the Engineer prior to start of fill placement.

No brush, roots, sod, or other deleterious or unsuitable materials shall be placed in the fills. The suitability of all fill materials intended for use in the embankment construction will be subject to approval by the Engineer. Fill shall not be placed upon saturated surfaces, frozen, or loose wind blown materials.

If the surface of the prepared foundation or the surface of any layer of the fill is too dry or too smooth to bond properly with the layer of material to be placed thereon, it shall be moistened and/or worked with harrow, scarifier, or other equipment to provide a satisfctory bonding surface before the next layer of fill material is placed. If the surface of the prepared foundation or the rolled surface of any layer of the fill in-place is too wet for proper compaction of the layer of fill material to be placed thereon, it shall be removed and allowed to dry or it shall be worked with harrow, scarifier, or other equipment to reduce the moisture content to the required amount. It shall then be compacted before the next layer of fill material is placed. Determination of such dry or wet conditions shall be by the Engineer.

The distribution of materials within any given zone shall be such that the fill is free from lenses, pockets, streaks, or layers of material differing substantially in texture or gradation from the surrounding material. The combined borrow excavation and fill placement operation shall be such that the materials, when compacted in the fill, will be blended sufficiently to secure the best practicable distribution of the material, subject to the approval of the Engineer. Where the gradations of two materials are not compatible, in the opinion of the Engineer, the Contractor shall place and compact, as specified, not less than 2 ft of material of an acceptable intermediate gradation between the incompatible materials.

Unless otherwise approved by the Engineer, the top of the fill shall be at or near the same elevation at all times during construction; the maximum permissible slope across the fill shall be 6 percent. At all times during construction, the surface of the fill shall be graded to prevent ponding of water and maintained to drain water.

Except as otherwise specified or approved by the Engineer, fill shall be dumped and spread in such a manner so that no gaps are left between successively-dumped loads of materials. The fill shall be leveled prior to compaction by means of a dozer or grader, or other suitable approved equipment, to obtain a surface free from depressions. Except in ares approved by the Engineer where space is limited or as otherwise specified, fill shall be placed in the fill by routing the hauling and spreading units approximately parallel to the axis of the fill; and as far as practical, the hauling units shall be so routed that they do not follow in the same paths but spread their tracks evenly over the surface of the fill. The Contractor shall not be permitted to end-dump fill materials into depressions in the foundations or to blade fill down slopes to fill depressions.

Unless otherwise approved by the Engineer, the slope of compacted soil faces against which compacted fill is to be placed shall not be steeper than 1.5 horizontal to 1.0 vertical.

9.2 GENERAL FILL

Fill material within the specification given in Section 5.2 shall be spread in horizontal layers not exceeding 8 inches in thickness prior to compaction. Where hand-operated tampers are to be used, the lift thickness shall not exceed 4 inches before compaction. The maximum allowable particle size in the 4-inch uncompacted lift shall be 3 inches. Sand material containing up to 50 percent fines may be placed in the same manner upon approval by the Engineer, otherwise placement shall be as specified in Section 9.3

9.3 FINE-GRAINED MATERIAL

In the event that material classified as fine-grained material is encountered in the excavation and upon approval of the Engineer, the fill material shall be spread in horizontal layers not exceeding 8 inches prior to compaction. Where hand-operated tampers are to be used, the lift thickness shall not exceed 4 inches before compaction. The maximum allowable particle size in the 4-inch uncompacted lift shall be 3 inches.

9.4 SECONDARY LINER

The material for the secondary liner shall be placed in such a manner so as not to damage or contaminate the underlying geofabric or leak detection system. The material shall be spread in at least two horizontal lifts. The final thickness upon completion of compaction shall be a minimum 12 inches. Materials shall be placed to lines and grades as shown on the drawings with a tolerance of ± 0.1 feet. The surface of the secondary liner shall be smooth with no abrupt changes.

10.0 COMPACTION

10.1 GENERAL

After each layer of fill material has been placed, spread, and moisture conditioned (as specified in Section 9.3), the layer shall be compacted by passing compaction equipment over the entire surface of the layer a sufficient number of times to obtain the required compaction to be verified on the basis of the specified quality assurance tests. Should the surface of the fill become rutted or uneven subsequent to compaction, it shall be re-leveled before the next layer of fill is placed and, if required by the Engineer, recompacted by and at the expense of the Contractor.

Compaction shall be accomplished by approved equipment. The Engineer will continuously evaluate the Contractor's equipment and methods. If such equipment or methods are found unsatisfactory for the intended use, the Engineer will require the Contractor to replace the unsatisfactory equipment with other types or adjust methods until proper compaction is achieved. Compaction for cohesive soils shall be based on ASTM D-698. A minimum compaction of 95 percent of the laboratory Standard Proctor dry density shall be achieved. Compaction of cohesionless soils shall provide a minimum relative density of 80 percent based on ASTM 2049.

Insofar as practical, the material shall be brought to the proper moisture content prior to placement in the fill. Supplementary water, if required, may be added to the material by sprinkling on the fill or preferably, on the borrow area, and it shall be mixed uniformly throughout the layer by harrowing or blading prior to compaction of the layer. Such addition of water is subject to the approval of the Engineer.

To aid in determining that the fill is being compacted as specified, quality assurance tests will be done under the direction of the Engineer at no cost to the Contractor. The Contractor shall supply labor for preparing test sites, if applicable and if requested by the Engineer. Each lift of fill must be approved by the Engineer before additional lifts are placed. A reasonable period of time shall be allowed for testing of the fill. When material has not been properly placed or compacted as determined by observations and quality assurance testing, such material shall be removed or reworked as necessary to obtain the required compaction at the Contractor's expense. It is the intent of this specification that tests and observations by the Engineer are for quality assurance purposes only, and the Contractor is solely responsible for providing the required tests and observations for quality control purposes.

10.2 REQUIRED COMPACTION

10.2.1 Cohesive/Fine-Grained Materials

Material for the site grading, subgrade, detention dike and secondary liner shall be compacted at the specified water content to an average dry density which is at least 95 percent of the maximum dry density determined by the laboratory test procedure ASTM Designation 698, Method A. When tested at a particular location, material compacted to a dry density less than 95 percent of maximum shall not be accepted. Changes in these specifications are subject to the approval of the Engineer.

In addition, the secondary liner material shall achieve a permeability of no greater than 1 x 10^{-7} cm/sec.

10.2.2 Leak Detection Material

No compaction is required on the granular material placed in the leak detection system.

10.2.3 Perimeter Berms

Material for perimeter berms shall be compacted to at least 95 percent of the maximum as determined by the ASTM Designation 698, Method A.

10.3 MOISTURE CONTROL

10.3.1 General

During compaction operations, the materials being placed and the surface of the fill shall be maintained within the moisture content range required to permit proper compaction to the specified density with the equipment being used. The moisture content of the fill materials prior to and during compaction shall be uniform throughout each layer of the material.

In general, the proposed borrow material is well dry of optimum moisture content. Where the material spread on the fill is drier than specified for compaction, the Contractor shall spray water on each layer of the fill or in the borrow area and work the moisture into the fill by harrowing or other approved means until a uniform distribution of moisture at the proper content is obtained. Material spread on the fill that is too wet for proper compaction shall be removed or it may be left on the fill and permitted to dry, assisted by discing and harrowing as necessary, until the moisture content is reduced to an amount suitable for obtaining the specified percent of compaction. If material is left on the fill to dry, no material may be placed over the wet material until it has been dried, reworked, and properly compacted.

Mixing of wet and dry material on the fill to obtain the proper moisture content shall not be done. Placing mixed material on the fill can only be done after the material has cured and a uniform distribution of the moisture content has been achieved and approved by the Engineer.

10.3.2 Application of Water

Water may be applied on the fill or in the borrow area from water trucks acceptable to the Engineer. It is the intent of this specification that adjustments in moisture content shall be made principally in the borrow area.

10.3.3 Cohesionless/Sand and Rock Fill

Sand fill materials shall be uniformly wetted prior to compaction sufficient to obtain a moisture content to prevent bulking.

10.3.4 Cohesive/Fine-Grained Material

Material classified as fine-grained shall be placed at a moisture content that is 1.0 percent dry to 2.0 percent wet of the optimum.

10.3.5 Secondary Liner Material

Material classified as fine-grained shall be placed at a moisture content that is 1.0 percent dry to 2.0 percent wet of the optimum.

10.4 CONDUCT OF WORK

The Contractor shall route his construction equipment and take all other actions necessary to prevent material of one type from being deposited inadvertently, either by dumping or through travel of equipment, in or on material of another type. Any improperly deposited material shall be removed from the embankment as required by the Engineer. Said removed material should not be reused and shall be wasted in locations designated by the Engineer.

Any stones of such dimensions that would interfere with compaction in the layer thicknesses specified, as determined by the Engineer, shall be removed from the zone in which they are placed prior to compaction.

The Contractor shall maintain and protect fills in a condition satisfactory to the Engineer at all times until the final completion and acceptance of the Work. Any approved fill material which becomes unsuitable for any reasons whatsoever, after being placed in the fill and before final acceptance of the Work, shall be removed and replaced in a manner satisfactory to the Engineer by the Contractor at his own cost.

10.5 COMPACTION EQUIPMENT

10.5.1 General

The Contractor shall provide sufficient compaction equipment of the types and sizes specified herein as is necessary for compaction of the various fill materials as specified in Section 9.2. The Contractor will be permitted to use alternative equipment, provided the Contractor can demonstrate to the Engineer that such alternate equipment will compact the fill material to a density not less than that which would be produced by the equipment specified; and that no undesirable features, such as stratification, will occur with the proposed alternate equipment. If the Contractor wishes to use alternative equipment, he shall submit to the Engineer for approval complete details of said equipment and the methods proposed for its use. The Engineer's approval of the use of alternative equipment will be conditional upon the Contractor's construction of test fills at his own expense. Any approval of alternate equipment will not relieve the Contractor from responsibility of obtaining the specified compaction.

Tractors used for pulling compaction equipment shall have sufficient power for the most adverse conditions to be encountered during compaction of the fill and when the compaction equipment is ballasted to the maximum weight specified. Compaction equipment shall be maintained in good condition at all times to obtain the maximum degree of compaction for the equipment being used. The Contractor shall immediately make adjustments to the equipment to achieve this end when specified by the Engineer.

The Contractor shall be in a position to provide and use, as specified, the following types of compactors.

10.5.2 Tamping Rollers

10.5.2.1 Description

Tamping rollers with a heavy-duty, double-drum unit shall be of the sheepsfoot type and shall have a minimum ballasted weight of 4,000 lbs per ft of width. The drum shall be water or sand-and-water ballasted. Each knob shall project a minimum of 7 inches from the drum. The projected face area of each tamping knob and the number of and spacing of the knobs shall be such that the total weight of the ballasted roller, when distributed over one row of knobs, will result in a minimum pressure of 500 lbs per sq inch, but not to exceed 750 lbs per sq inch. The roller shall be equipped with cleaning fingers so designed and attached as to prevent an accumulation of material between the tamping feet.

10.5.2.2 Types of Tamping Rollers

The roller shall be self-propelled or pulled by a crawler-type tractor of sufficient power to operate the roller at a speed of approximately 3 mph. The design and operation of the roller will be subject to approval of the Engineer, and the Contractor shall at any time make such minor alterations or adjustments to the operations or equipment, as directed by the Engineer, to secure optimum compaction.

10.5.2.3 Hand-Operated Tampers

Pneumatic tampers or gasoline-powered rammers may be used in areas where it is impractical or undesirable to use tamping rollers. The operation of the hand-operated tampers shall be subject to the approval of the Engineer and shall result in compaction equivalent to that obtained from Section 9.5.2.2.

10.5.3 Pneumatic-Tired Rollers

Pneumatic-tired rollers shall have a minimum of four wheels equipped with pneumatic tires, and a body suitable for ballast loading such that the load per wheel can be varied up to 30,000 lbs. The roller wheels shall be located abreast and be designed such that each wheel exerts approximately the same load under any condition likely to be encountered during its use, especially conditions met in traversing uneven ground. The tires shall be such that tire pressures during roller operations can be maintained at approximately 90 lbs per sq inch. The spacing of the wheels shall be such that the distance between adjacent tire imprints during rolling will not be greater than 50 percent of the width of a single tire.

10.5.4 Vibratory Rollers

Vibratory rollers shall be of the vibratory, smooth, single steel-drum type and shall be equipped with a suitable cleaning device to prevent the accumulation of material on the drum during rolling. Each roller shall have a total static weight of not less than 10 tons with at least 90 percent of this weight being transmitted to the ground through the drum when the roller is standing on level ground and attached to the pulling equipment. The drum shall not be less than 50 inches in diameter and 72 inches in width. The vibration frequency of the roller during operation shall be between 1,100 and 1,800 vibrations per minute. Self-propelled vibratory rollers may be used, subject to the approval of the Engineer.

10.5.5 Special Compactors

Special compactors may include:

- Loaded dump trucks;
- Hand guided, heavy-duty mechanical tampers;
- Hand guided vibratory rollers; and
- Such other compaction equipment as may be approved by the Engineer for use in restricted areas or near certain critical installations.

Special compactors shall be capable of producing, with a reasonable number of coverages, the specified densities in the fill material on which they are used.

Only hand-guided mechanical tampers or hand-guided vibratory rollers shall be used for compaction around, over, near, or adjacent to pipes, culverts, and concrete structures.

11.0 QUALITY ASSURANCE TESTS

11.1 GENERAL

Quality assurance (QA) tests shall be done on compacted fill materials as outlined in Section 10.3. The tests shall be run in accordance with acceptable procedures developed for the tests. QA for the liner installation shall be as outlined in Section 6.0. All laboratory QA tests shall be performed by a certified laboratory. Results shall be submitted to North Lily Mining Company and appropriate state agencies.

11.2 QA TESTS

Tests to be run for QA purposes are listed below. Tests not listed may be run at the direction of the Engineer. The Engineer or his representative will designate the materials to be tested and the tests to be done.

The typical construction control tests are:

- Six-inch sand cone field density;
- Moisture-density test with nuclear gage;
- Moisture content;
- Rapid compaction test;
- Grain-size distribution; and
- Atterberg limits.

11.3 QA TEST SCHEDULE

PVC Liners:

- Field coupon test every 250 ft of seam.

Secondary liner, each lift and prepared foundation:

- Moisture/density test on 50 ft by 50 ft grid system;

- Gradation tests on 200 ft x 200 ft grid system;
- Compaction curve on 200 ft x 200 ft grid system, unless rapid compaction tests run; and
- Permeability samples on a 200 x 200 ft grid.

General Fill:

- Moisture/density test on 50 ft by 50 ft grid system or per 100 cy placed, whichever is greater.
- Gradation tests on a 200 ft x 200 ft grid system, unless rapid compaction test run; and
- Compaction curve on 200 ft x 200 ft grid system.

Berms:

- Gradation tests every 250 lineal ft of berm.
- Compaction curve every 250 lineal ft of berm.

TEST DATA AND PROCEDURES

RESULTS OF TESTS ON PROPOSED HEAP MATERIAL

TRIAXIAL COMPRESSION TEST:

Friction Angle, 41 degrees

Cohesion, 331 psf

BACKPRESSURE PERMEABILITY TESTS:

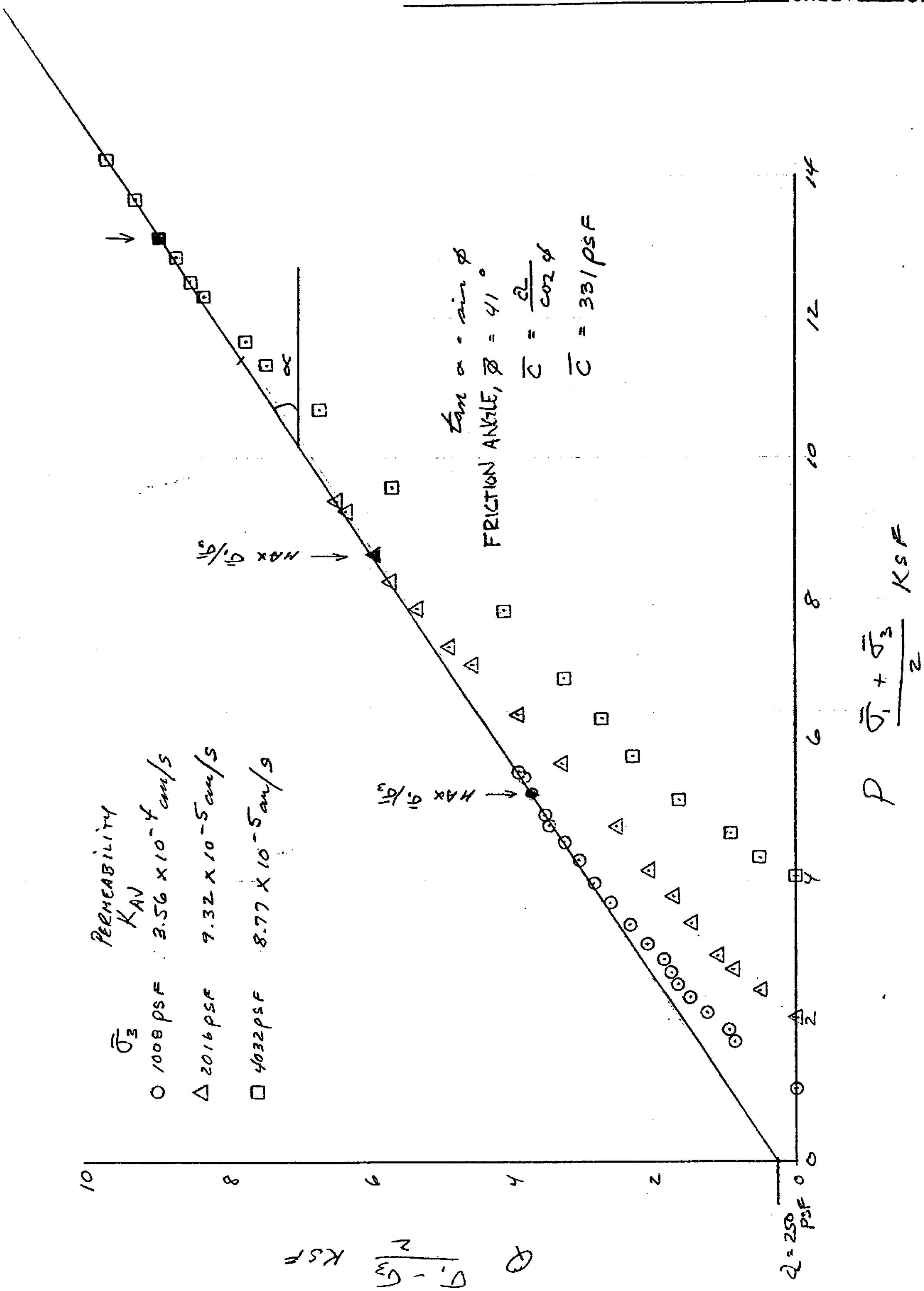
Permeability at 1008 psf confining pressure, 2.56×10^{-4} cm/sec

Permeability at 2016 psf confining pressure, 9.32×10^{-5} cm/sec

Permeability at 4032 psf confining pressure, 8.77×10^{-5} cm/sec

FILE North Lilly Mining
SUBJECT
SHEET ___ OF ___

REVISIONS
BY ___ DATE ___ TO EO ___
BY ___ DATE ___ TO EO ___



BY ___ DATE 7/15/80
CHECKED BY
COPY TO EO

Dames & Moore

4 (12-73) PRINTED IN U.S.A.

OWNER N. Lilly Mining Corp. 19245-002
BORING Bulk Sample
SAMPLE Remold - Loose
DEPTH Agglomerated Recd 8-31-1990 Phase @ 1008 PSF

INITIAL MOISTURE CONTENT %	DRY DENSITY PCF	FINAL MOISTURE CONTENT %	DRY DENSITY PCF
4.2	125.0	12.6	125.4

CONSOLIDATION PRESSURE, INITIAL = 1008 PSF

STR. %	PWP PSF	SIG1-SIG3 STRESS	SIG3E PSF	SIG1E PSF	Q PSF	P PSF	S1/ S3
0.09	144.0	1652.8	864.0	2516.8	826.4	1690.4	2.91
0.15	158.4	1952.2	849.6	2801.8	976.1	1825.7	3.30
0.18	165.6	2251.7	842.4	3094.1	1125.9	1968.3	3.67
0.22	169.9	2551.0	838.1	3389.1	1275.5	2113.6	4.04
0.28	180.0	2699.6	828.0	3527.6	1349.8	2177.8	4.26
0.30	172.8	2999.0	835.2	3834.2	1499.5	2334.7	4.59
0.39	158.4	3146.0	849.6	3995.6	1573.0	2422.6	4.70
0.44	144.0	3294.0	864.0	4158.0	1647.0	2511.0	4.81
0.52	129.6	3590.8	878.4	4469.2	1795.4	2673.8	5.09
0.59	100.8	3887.1	907.2	4794.3	1943.6	2850.8	5.28
0.65	86.4	4034.4	921.6	4956.0	2017.2	2938.8	5.38
0.68	72.0	4182.2	936.0	5118.2	2091.1	3027.1	5.47
0.92	0.0	4768.1	1008.0	5776.1	2384.1	3392.1	5.73
1.07	-28.8	5207.3	1036.8	6244.1	2603.7	3640.5	6.02
1.26	-100.8	5494.6	1108.8	6603.4	2747.3	3856.1	5.96
1.39	-158.4	5635.7	1166.4	6802.1	2817.9	3984.3	5.83
1.66	-230.4	6063.5	1238.4	7301.9	3031.8	4270.2	5.90
1.76	-259.2	6205.6	1267.2	7472.8	3102.8	4370.0	5.90
1.90	-288.0	6491.3	1296.0	7787.3	3245.7	4541.7	6.01
2.18	-331.2	6914.3	1339.2	8253.5	3457.1	4796.3	6.16
2.31	-388.8	7052.1	1396.8	8448.9	3526.0	4922.8	6.05
2.55	-460.8	7474.4	1468.8	8943.2	3737.2	5206.0	6.09
2.74	-532.8	7752.7	1540.8	9293.5	3876.4	5417.2	6.03
2.83	-561.6	7891.5	1569.6	9461.1	3945.8	5515.4	6.03
3.16	-619.2	8155.8	1627.2	9783.0	4077.9	5705.1	6.01

OWNER NLM 19245-002
BORING Bulk Sample
SAMPLE Remold loose
DEPTH Agglomerated recd 8-31-90 Phase @ 2016 PSF

INITIAL MOISTURE CONTENT %	DRY DENSITY PCF	FINAL MOISTURE CONTENT %	DRY DENSITY PCF
4.2	125.0	12.6	125.6

CONSOLIDATION PRESSURE, INITIAL = 2016 PSF

STR. %	PWP PSF	SIG1-SIG3 STRESS	SIG3E PSF	SIG1E PSF	Q PSF	P PSF	S1/ S3
0.02	115.2	1027.8	1900.8	2928.6	513.9	2414.7	1.54
0.06	129.6	1761.3	1886.4	3647.7	880.7	2767.1	1.93
0.11	144.0	2200.4	1872.0	4072.4	1100.2	2972.2	2.18
0.19	86.4	2931.6	1929.6	4861.2	1465.8	3395.4	2.52
0.25	-14.4	3515.9	2030.4	5546.3	1758.0	3788.4	2.73
0.28	-86.4	4100.3	2102.4	6202.7	2050.2	4152.6	2.95
0.38	-216.0	5120.6	2232.0	7352.6	2560.3	4792.3	3.29
0.49	-316.8	6576.0	2332.8	8908.8	3288.0	5620.8	3.82
0.63	-403.2	7880.7	2419.2	10299.9	3940.4	6359.6	4.26
0.80	-417.6	9178.4	2433.6	11612.0	4589.2	7022.8	4.77
0.91	-432.0	9749.9	2448.0	12197.9	4875.0	7323.0	4.98
1.02	-446.4	10174.8	2462.4	12637.2	5087.4	7549.8	5.13
1.23	-475.2	10733.5	2491.2	13224.7	5366.8	7858.0	5.31
1.39	-475.2	11006.7	2491.2	13497.9	5503.3	7994.5	5.42
1.56	-547.2	11276.8	2563.2	13840.0	5638.4	8201.6	5.40
1.69	-547.2	11405.9	2563.2	13969.1	5703.0	8266.2	5.45
2.03	-633.6	11941.8	2649.6	14591.4	5970.9	8620.5	5.51
2.28	-691.2	12198.8	2707.2	14906.0	6099.4	8806.6	5.51
2.69	-835.2	12718.3	2851.2	15569.5	6359.1	9210.3	5.46
2.85	-864.0	12841.1	2880.0	15721.1	6420.5	9300.5	5.46
3.00	-892.8	12963.5	2908.8	15872.3	6481.7	9390.5	5.46

OWNER NLM 19245-002
BORING Bulk Sample
SAMPLE Agglomerated Remold Loose
DEPTH Rec'd 8-31-1990 PHASE @ 4032 PSF

INITIAL MOISTURE CONTENT %	DRY DENSITY PCF	FINAL MOISTURE CONTENT %	DRY DENSITY PCF
4.2	125.0	12.6	126.1

CONSOLIDATION PRESSURE, INITIAL = 4032 PSF

STR. %	PWP PSF	SIG1-SIG3 STRESS	SIG3E PSF	SIG1E PSF	Q PSF	P PSF	S1/ S3
0.02	216.0	1007.6	3816.0	4823.6	503.8	4319.8	1.26
0.04	331.2	1870.8	3700.8	5571.6	935.4	4636.2	1.51
0.10	518.4	3308.0	3513.6	6821.6	1654.0	5167.6	1.94
0.17	547.2	4598.9	3484.8	8083.7	2299.5	5784.3	2.32
0.23	489.6	5458.0	3542.4	9000.4	2729.0	6271.4	2.54
0.29	403.2	6459.7	3628.8	10088.5	3229.8	6858.6	2.78
0.41	302.4	8172.7	3729.6	11902.3	4086.3	7815.9	3.19
0.60	86.4	11304.9	3945.6	15250.5	5652.5	9598.1	3.87
0.78	57.6	13427.8	3974.4	17402.2	6713.9	10688.3	4.38
0.99	100.8	14824.3	3931.2	18755.5	7412.1	11343.3	4.77
1.17	144.0	15509.6	3888.0	19397.6	7754.8	11642.8	4.99
1.63	57.6	16711.0	3974.4	20685.4	8355.5	12329.9	5.20
1.85	43.2	17098.6	3988.8	21087.4	8549.3	12538.1	5.29
2.10	-57.6	17477.5	4089.6	21567.1	8738.8	12828.4	5.27
2.43	-129.6	17980.4	4161.6	22142.1	8990.2	13151.8	5.32
2.62	-216.0	18225.0	4248.0	22473.0	9112.5	13360.5	5.29
3.03	-331.2	18567.5	4363.2	22930.7	9283.8	13647.0	5.26
3.69	-518.4	19411.7	4550.4	23962.1	9705.8	14256.2	5.27
4.66	-820.8	20314.0	4852.8	25166.8	10157.0	15009.8	5.19
5.24	-993.6	20735.5	5025.6	25761.1	10367.8	15393.4	5.13
5.87	-1195.2	21277.2	5227.2	26504.4	10638.6	15865.8	5.07
6.80	-1454.4	22005.7	5486.4	27492.1	11002.9	16489.3	5.01
7.26	-1540.8	22029.2	5572.8	27602.0	11014.6	16587.4	4.95
8.02	-1656.0	22511.4	5688.0	28199.4	11255.7	16943.7	4.96
8.72	-1814.4	22734.5	5846.4	28580.9	11367.2	17213.6	4.89
10.02	-1972.8	23187.6	6004.8	29192.4	11593.8	17598.6	4.86
10.78	-2073.6	23506.2	6105.6	29611.8	11753.1	17858.7	4.85
11.83	-2145.6	23610.7	6177.6	29788.3	11805.4	17983.0	4.82
12.43	-2232.0	23953.8	6264.0	30217.8	11976.9	18240.9	4.82
12.72	-2260.8	23999.8	6292.8	30292.6	11999.9	18292.7	4.81
13.50	-2289.6	24035.2	6321.6	30356.8	12017.6	18339.2	4.80
14.35	-2376.0	24167.7	6408.0	30575.7	12083.9	18491.9	4.77
15.65	-2534.4	24407.7	6566.4	30974.1	12203.9	18770.3	4.72

Dames & Moore

TRIAXIAL TEST DATA SHEET
LOW PRESSURE-ENGLISH

Owner: NORTH LILLY MINING
Job #: 19245-002
Location: EUREKA UT.
Boring #: BULK SAMPLE
Sample #: AGGLOMERATED REC'D 8/31/90
Depth: REMOLD - LOOSE AS POSSIBLE

Deflecting Speed: .001 in/Hr/Min
Lateral Pressure: 1000, 2000, 4000 PSF/PSI @ P6p
Saturated ☒ Field Moisture ☐
Set-Up: 9/ Tested: ____ (____ Office)
Soil Type: ____

		Initial	Final	
Weight soil & dish no.			1081.3	NB
Dry weight soil & dish			978.9	
Net loss of moisture				
Weight of dish only			165.0	
Net weight of dry soil				
Moisture, % of dry weight		4.2	12.6	
Wt. solids + moisture	W_0	848.3	916.6	gms.
$W_0 \div 454$	W_0'		2.0159	lbs.
Weight solids	W_s		814.0	gms.
Wet density $W_0' \div V_0'$				pcf
Dry density				pcf
Net diameter	D_0	2.416		in.
Area ($0.785\ D_0^2$)	A_0	4.582	4.774	sq. in
Height	H_0	5.41	5.149	in.
Volume $(A_0H_0) \div 1728$	V_0'		.01422	cu. ft.
Volume $(A_0H_0) \times 16.4$	V_0			cc
Specific gravity of solids	G_s			
Volume of solids $W_s \div G_s$	V_s			cc
$(V_0 - V_s) \div V_s$	e_i			
Initial burette reading				cc
Burette reading under pressure				cc
$(V_p - V_s) \div V_s$	e_p			

PERMEABILITY TEST BY BACK PRESSURE CONSTANT-HEAD

PHASE 1008 PSF

North Lilly Mining Company Eureka Utah

Bulk Sample Received 8-31-1990
Sample Agglomerated Remold - Loose

	Initial	Final
Wet Density pcf	130.2	~~141.2~~
Dry density pcf	125.0	~~135.5~~
% Moisture	4.2	~~12.6~~

Height Initial	5.410	948.3	Wet soil and dish
Diameter Initial	2.416	914	Dry soil and dish
Area Initial	4.582	100	dish only
Volume Initial	406.54	848.3	Ws Initial
Initial dial	0.135	916.6	Final Ws
Final dial	0.137	814.0	Weight solids
Initial cc/in res	-0.416		
Final cc/in res.	-0.322		

Height Final	5.408	13.736 cm
Diameter Final	2.413	
Area Final	4.570	29.505 cm^2
Volume Final	405.29	

Height change	-0.002	
cc/in reser.	0.008	
Volume change	-11.75	
Cell Change	10.5	
Net Volume Change	-1.25	
h= T/B PREss. diff	4	280.40 cm

Standard Water .005 N $CaSO_4$

Hydraulic Gradient
20.41

Elapsed Time minutes	cc's	K cm/sec
0.5	7.30	3.76E-04
0.5	7.30	3.76E-04
0.5	6.80	3.50E-04
0.25	3.10	3.19E-04

K Average = 3.56E-04 cm/s

PERMEABILITY TEST BY BACK PRESSURE CONSTANT-HEAD

PHASE 2016 PSF

North Lilly Mining Company Eureka Utah

Bulk Sample Received 8-31-1990
Sample Agglomerated Remold - Loose

	Initial	Final
Wet Density pcf	130.2	~~141.4~~
Dry density pcf	125.0	~~135.7~~
% Moisture	4.2	~~12.6~~

Height Initial	5.410		948.3	Wet soil and dish
Diameter Initial	2.416		914	Dry soil and dish
Area Initial	4.582		100	dish only
Volume Initial	406.54		848.3	Ws Initial
Initial dial	0.135		916.6	Final Ws
Final dial	0.275		814.0	Weight solids
Initial cc/in res	-0.416			
Final cc/in res.	-0.31			
Height Final	5.270	13.386 cm		
Diameter Final	2.442			
Area Final	4.680	30.218 cm^2		
Volume Final	404.49			
Height change	-0.14			
cc/in reser.	0.008			
Volume change	-13.25			
Cell Change	11.2			
Net Volume Change	-2.05			
h= T/B PREss. diff	4	280.40 cm		

Standard Water .005 N CaSO4

Hydraulic Gradient
20.95

Elapsed Time minutes	cc's	K cm/sec
0.5	1.80	8.82E-05
0.5	2.60	1.27E-04
0.5	1.60	7.84E-05
0.50	1.60	7.84E-05

K Average = 9.32E-05 cm/s

PERMEABILITY TEST BY BACK PRESSURE CONSTANT-HEAD

PHASE 4032 PSF

North Lilly Mining Company Eureka Utah
AGGLOMERATED Sample Received 8-31-90
Remold Loose

		Initial	Final
Wet Density	pcf	130.2	141.9
Dry density	pcf	125.0	126.0
% Moisture		4.2	12.6

Height Initial	5.410		948.3	Wet soil and dish
Diameter Initial	2.416		914	Dry soil and dish
Area Initial	4.582		100	dish only
Volume Initial	406.54		848.3	Ws Initial
Initial dial	0.135		916.6	Final Ws
Final dial	0.396		814.0	Weight solids
Initial cc/in res	-0.416			
Final cc/in res.	-0.288			
Height Final	5.149	13.078 cm		
Diameter Final	2.466			
Area Final	4.774	30.825 cm^2		
Volume Final	403.14			
Height change	-0.261			
cc/in reser.	0.008			
Volume change	-16			
Cell Change	12.6			
Net Volume Change	-3.4			
h= T/B PREss. diff	7	490.70 cm		

Standard Water .005 N CaSO4

Hydraulic Gradient
37.52

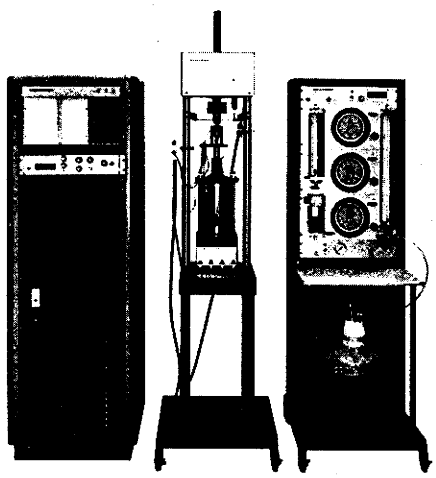
Elapsed Time minutes	cc's		K cm/sec
0.5	3.80		1.02E-04
0.5	3.40	*	9.12E-05
0.5	3.20	*	8.59E-05
0.5	3.20	*	8.59E-05

*
K Average = 8.77E-05 cm/s

LABORATORY TEST PROCEDURES

THE SHEARING STRENGTHS OF SOILS ARE DETERMINED FROM THE RESULTS OF UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS. IN TRIAXIAL COMPRESSION TESTS THE TEST METHOD AND THE MAGNITUDE OF THE CONFINING PRESSURE ARE CHOSEN TO SIMULATE ANTICIPATED FIELD CONDITIONS.

UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS ARE PERFORMED ON UNDISTURBED OR REMOLDED SAMPLES OF SOIL APPROXIMATELY SIX INCHES IN LENGTH AND TWO AND ONE-HALF INCHES IN DIAMETER. THE TESTS ARE RUN EITHER STRAIN-CONTROLLED OR STRESS-CONTROLLED. IN A STRAIN-CONTROLLED TEST THE SAMPLE IS SUBJECTED TO A CONSTANT RATE OF DEFLECTION AND THE RESULTING STRESSES ARE RECORDED. IN A STRESS-CONTROLLED TEST THE SAMPLE IS SUBJECTED TO EQUAL INCREMENTS OF LOAD WITH EACH INCREMENT BEING MAINTAINED UNTIL AN EQUILIBRIUM CONDITION WITH RESPECT TO STRAIN IS ACHIEVED.



TRIAXIAL COMPRESSION TEST UNIT

YIELD, PEAK, OR ULTIMATE STRESSES ARE DETERMINED FROM THE STRESS-STRAIN PLOT FOR EACH SAMPLE AND THE PRINCIPAL STRESSES ARE EVALUATED. THE PRINCIPAL STRESSES ARE PLOTTED ON A MOHR'S CIRCLE DIAGRAM TO DETERMINE THE SHEARING STRENGTH OF THE SOIL TYPE BEING TESTED.

UNCONFINED COMPRESSION TESTS CAN BE PERFORMED ONLY ON SAMPLES WITH SUFFICIENT COHESION SO THAT THE SOIL WILL STAND AS AN UNSUPPORTED CYLINDER. THESE TESTS MAY BE RUN AT NATURAL MOISTURE CONTENT OR ON ARTIFICIALLY SATURATED SOILS.

IN A TRIAXIAL COMPRESSION TEST THE SAMPLE IS ENCASED IN A RUBBER MEMBRANE, PLACED IN A TEST CHAMBER, AND SUBJECTED TO A CONFINING PRESSURE THROUGHOUT THE DURATION OF THE TEST. NORMALLY, THIS CONFINING PRESSURE IS MAINTAINED AT A CONSTANT LEVEL, ALTHOUGH FOR SPECIAL TESTS IT MAY BE VARIED IN RELATION TO THE MEASURED STRESSES. TRIAXIAL COMPRESSION TESTS MAY BE RUN ON SOILS AT FIELD MOISTURE CONTENT OR ON ARTIFICIALLY SATURATED SAMPLES. THE TESTS ARE PERFORMED IN ONE OF THE FOLLOWING WAYS:

> <u>UNCONSOLIDATED-UNDRAINED:</u> THE CONFINING PRESSURE IS IMPOSED ON THE SAMPLE AT THE START OF THE TEST. NO DRAINAGE IS PERMITTED AND THE STRESSES WHICH ARE MEASURED REPRESENT THE SUM OF THE INTERGRANULAR STRESSES AND PORE WATER PRESSURES.

> <u>CONSOLIDATED-UNDRAINED:</u> THE SAMPLE IS ALLOWED TO CONSOLIDATE FULLY UNDER THE APPLIED CONFINING PRESSURE PRIOR TO THE START OF THE TEST. THE VOLUME CHANGE IS DETERMINED BY MEASURING THE WATER AND/OR AIR EXPELLED DURING CONSOLIDATION. NO DRAINAGE IS PERMITTED DURING THE TEST AND THE STRESSES WHICH ARE MEASURED ARE THE SAME AS FOR THE UNCONSOLIDATED-UNDRAINED TEST.

> <u>DRAINED:</u> THE INTERGRANULAR STRESSES IN A SAMPLE MAY BE MEASURED BY PERFORMING A DRAINED, OR SLOW, TEST. IN THIS TEST THE SAMPLE IS FULLY SATURATED AND CONSOLIDATED PRIOR TO THE START OF THE TEST. DURING THE TEST, DRAINAGE IS PERMITTED AND THE TEST IS PERFORMED AT A SLOW ENOUGH RATE TO PREVENT THE BUILDUP OF PORE WATER PRESSURES. THE RESULTING STRESSES WHICH ARE MEASURED REPRESENT ONLY THE INTERGRANULAR STRESSES. THESE TESTS ARE USUALLY PERFORMED ON SAMPLES OF GENERALLY NON-COHESIVE SOILS, ALTHOUGH THE TEST PROCEDURE IS APPLICABLE TO COHESIVE SOILS IF A SUFFICIENTLY SLOW TEST RATE IS USED.

AN ALTERNATE MEANS OF OBTAINING THE DATA RESULTING FROM THE DRAINED TEST IS TO PERFORM AN UNDRAINED TEST IN WHICH SPECIAL EQUIPMENT IS USED TO MEASURE THE PORE WATER PRESSURES. THE DIFFERENCES BETWEEN THE TOTAL STRESSES AND THE PORE WATER PRESSURES MEASURED ARE THE INTERGRANULAR STRESSES.

METHODS OF PERFORMING UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS

DAMES & MOORE

946.7 (REV. 6-61)

the same as those described previously for each test.

6. PERMEABILITY TEST WITH PRESSURE CHAMBER. In the permeability test with a pressure chamber, see Figure 7, a cylindrical specimen is confined in a rubber membrane and subjected to an external hydrostatic pressure during the permeability test. The advantages of this type of test are: (a) leakage along the sides of the specimen, which would occur if the specimen were tested in a permeameter, is prevented, and (b) the specimen can be tested under conditions of loading expected in the field. The test is applicable primarily to cohesive soils in the undisturbed, remolded, or compacted state. Complete saturation of the specimen, if it is not fully saturated initially, is practically impossible. Consequently, this test should be used only for soils that are fully saturated, unless values of permeability are purposely desired for soils in an unsaturated condition. The permeability test with the pressure chamber is usually performed as a falling-head test.

The permeability specimens for use in the pressure chamber generally should be 2.8 in. in diameter, as rubber membranes and equipment for cutting and trimming specimens of this size are available for triaxial testing apparatus (see Appendix X, TRIAXIAL COMPRESSION TESTS). A specimen length of about 4 in. is adequate. (The dimensions of a test specimen may be varied if equipment and supplies are available to make a suitable test setup.) The pressure in the chamber should not be less than the maximum head on the specimen during the test. The other test procedure and computations are the same as those described for the falling-head test. The linear relation between permeability and void ratio on a semilogarithmic plot as shown in Figure 6 is usually not applicable to fine-grained soils, particularly when compacted. Other methods of presenting permeability-void ratio data may be desirable.

7. PERMEABILITY TESTS WITH BACK PRESSURE.

a. Description. Gas bubbles in the pores of a compacted or undisturbed specimen of fine-grained soil will invalidate the results of the permeability tests described in the preceding paragraphs. It is known that an increase in pressure will cause a reduction in volume of gas bubbles and also an increased weight of gas dissolved in water. To each degree of saturation there corresponds a certain additional pressure (back pressure) which, if applied to the pore fluid of the specimen, will cause complete saturation. The permeability test with back pressure is performed in a pressure chamber such as that shown in Figure 8, utilizing equipment that permits increasing the chamber pressure and pore pressure simultaneously, maintaining their difference constant. The method is generally applicable to fine-grained soils that are not fully saturated. Apparatus and procedures have been described by A. Casagrande† and L. Bjerrum and J. Huder.‡

b. Procedure (see Fig. 8). The procedure shall consist of the following steps:

(1) After having determined the dimensions and wet weight of the test specimen, place it in the triaxial apparatus, using the same procedure as for setting up a specimen for an R triaxial test with pore pressure measurements except that filter strips should not be used (see para 7, APPENDIX X, TRIAXIAL COMPRESSION TESTS).

(2) Saturate the specimen and verify 100 percent saturation using the procedure described in paragraph 7b, APPENDIX X, TRIAXIAL COMPRESSION TESTS. Burette "A" is utilized during this operation.

(3) With the drainage valves closed, increase the chamber

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† Casagrande, A., "Third Progress Report on Investigation of Stress Deformation and Strength Characteristics of Compacted Clays," Soil Mechanics Series No. 70, Nov 1963, Harvard University, Cambridge, Mass., pp 30 and 31.

‡ Bjerrum, L. and Huder, J., "Measurement of the Permeability of Compacted Clays," Proceedings, Fourth International Conference on Soil Mechanics and Foundation Engineering, London, Vol 1, Aug 1957, pp 6-8.

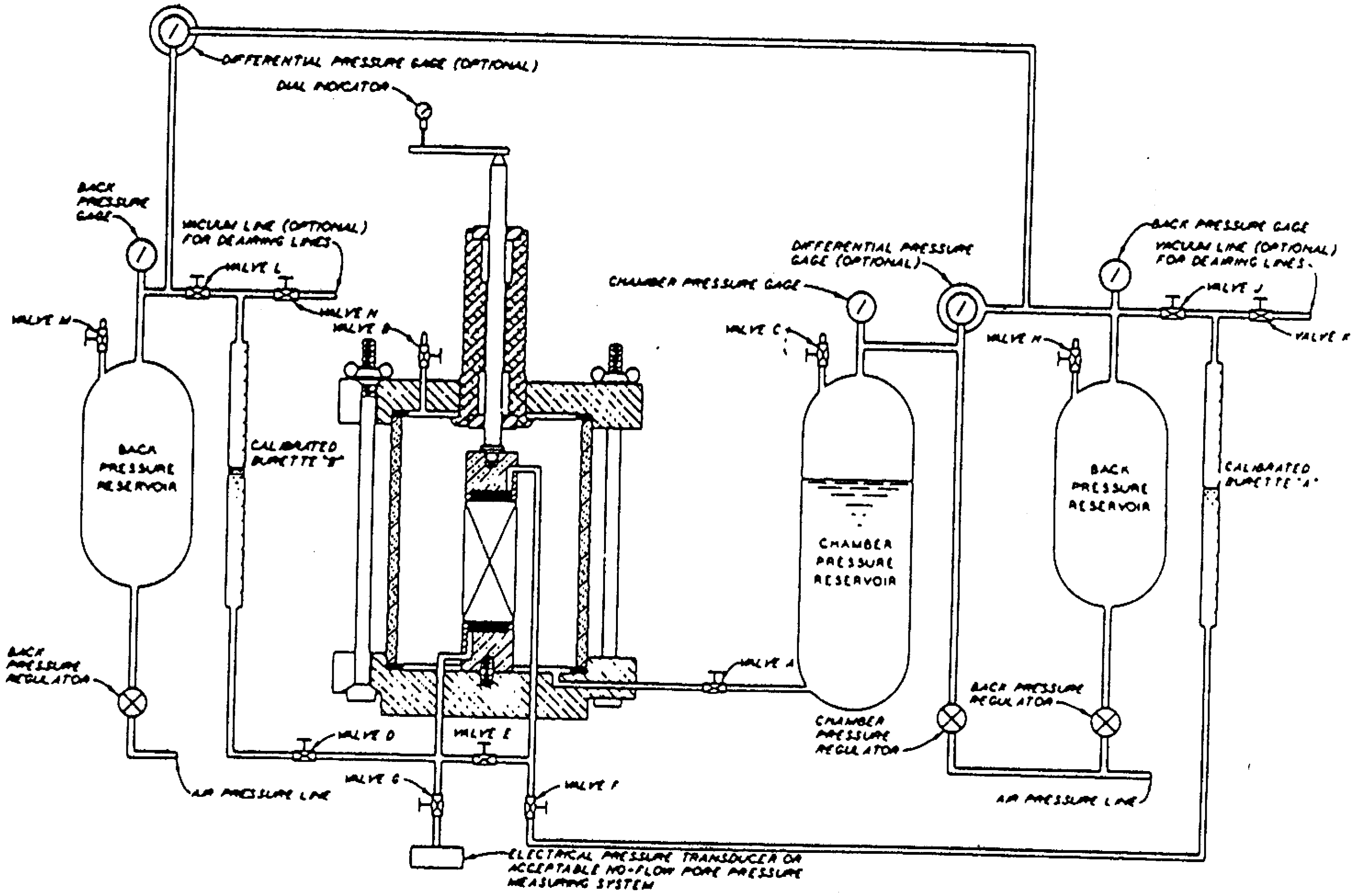


Figure 8. Schematic diagram of typical triaxial compression apparatus for permeability tests with back pressure

pressure to attain the desired effective consolidation pressure (chamber pressure minus back pressure). At zero elapsed time, open valves E and F.

(4) Record time, dial indicator reading, and burette reading at elapsed times of 0, 15, and 30 sec, 1, 2, 4, 8, and 15 min, and 1, 2, 4, and 8 hr, etc. Plot the dial indicator readings and burette readings on an arithmetic scale versus elapsed time on a log scale. When the consolidation curves indicate that primary consolidation is complete, close valves E and F.

(5) Apply a pressure to burette B greater than that in burette A. The difference between the pressures in burettes B and A is equal to the head loss h; h divided by the height of the specimen after consolidation, L, is the hydraulic gradient. The difference between the two pressures should be kept as small as practicable, consistent with the requirement that the rate of flow be large enough to make accurate measurements of the quantity of flow within a reasonable period of time. Because the difference in the two pressures may be very small in comparison to the pressures at the ends of the specimen, and because the head loss must be maintained constant throughout the test, the difference between the pressures within the burettes must be measured accurately; a differential pressure gage is very useful for this purpose. The difference between the elevations of the water within the burettes should also be considered (1 in. of water = 0.036 psi of pressure).

(6) Open valves D and F. Record the burette readings at any zero elapsed time. Make readings of burettes A and B and of temperature at various elapsed times (the interval between successive readings depends upon the permeability of the soil and the dimensions of the specimen). Plot arithmetically the change in readings of both burettes versus time. Continue making readings until the two curves become parallel and straight over a sufficient length of time to accurately determine the rate of flow (slope of the curves).

(7) If it is desired to determine the permeability at several void ratios, steps 3 through 6 can be repeated, using different consolidation pressures in step 3.

(8) At the end of the permeability determinations, close all drainage valves and reduce the chamber pressure to zero; disassemble the apparatus.

(9) Determine the wet and dry weights of the specimen.

c. Computations. The computations consist of the following steps.

(1) Compute the test void ratios as outlined in paragraph 3e(1).

(2) Computations of coefficients of permeability are the same as those described for the constant-head permeability test.

8. PERMEABILITY TESTS WITH CONSOLIDOMETER. A permeability test in a consolidometer (see Appendix VIII, CONSOLIDATION TEST) is essentially similar to that conducted in a pressure chamber, except that the specimen is placed within a relatively rigid ring and is loaded vertically. The test can be used as an alternate to the permeability test in the pressure chamber. The test is applicable primarily to cohesive soils in a fully saturated condition. Testing is usually performed under falling-head conditions.

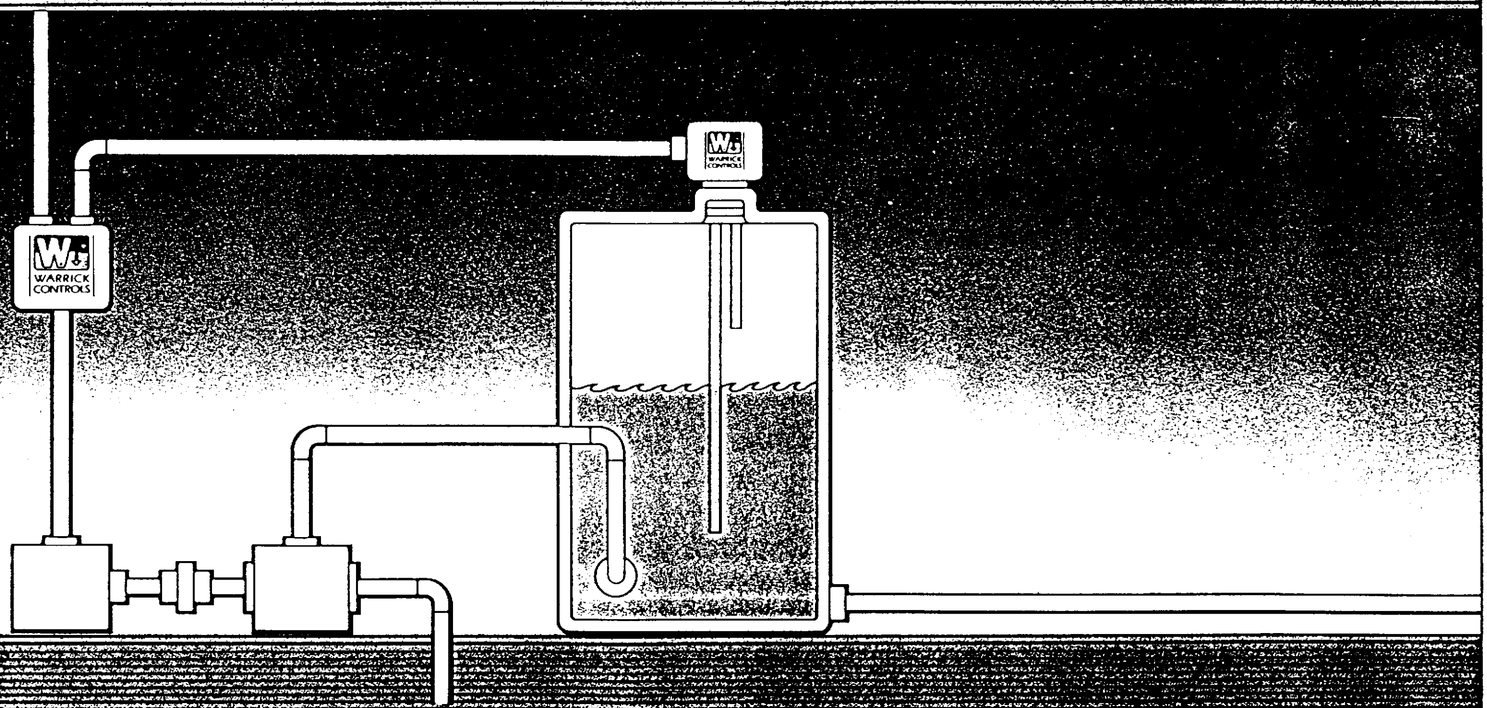
A schematic diagram of the consolidation apparatus set up for a falling-head permeability test is shown in Figure 9. Identifying information for the specimen and subsequent test data are entered on a data sheet (Plate VII-3 is a suggested form). The specimen should be placed in the specimen ring and the apparatus assembled as outlined under Appendix VIII, CONSOLIDATION TEST. The specimen is consolidated under the desired load and the falling-head test is performed as previously described. The

Catalog No. 200B

Warrick Liquid Level Controls

When level control is absolutely essential.

WARRICK CONTROLS



The basic control system.

The typical Warrick conductance probe-type liquid level control system consists of three major components: 1) the control, 2) the electrode fitting and 3) one or more electrodes.

The fixed, level-sensing electrodes are installed vertically with their lower ends positioned at the levels at which the control is to be actuated.

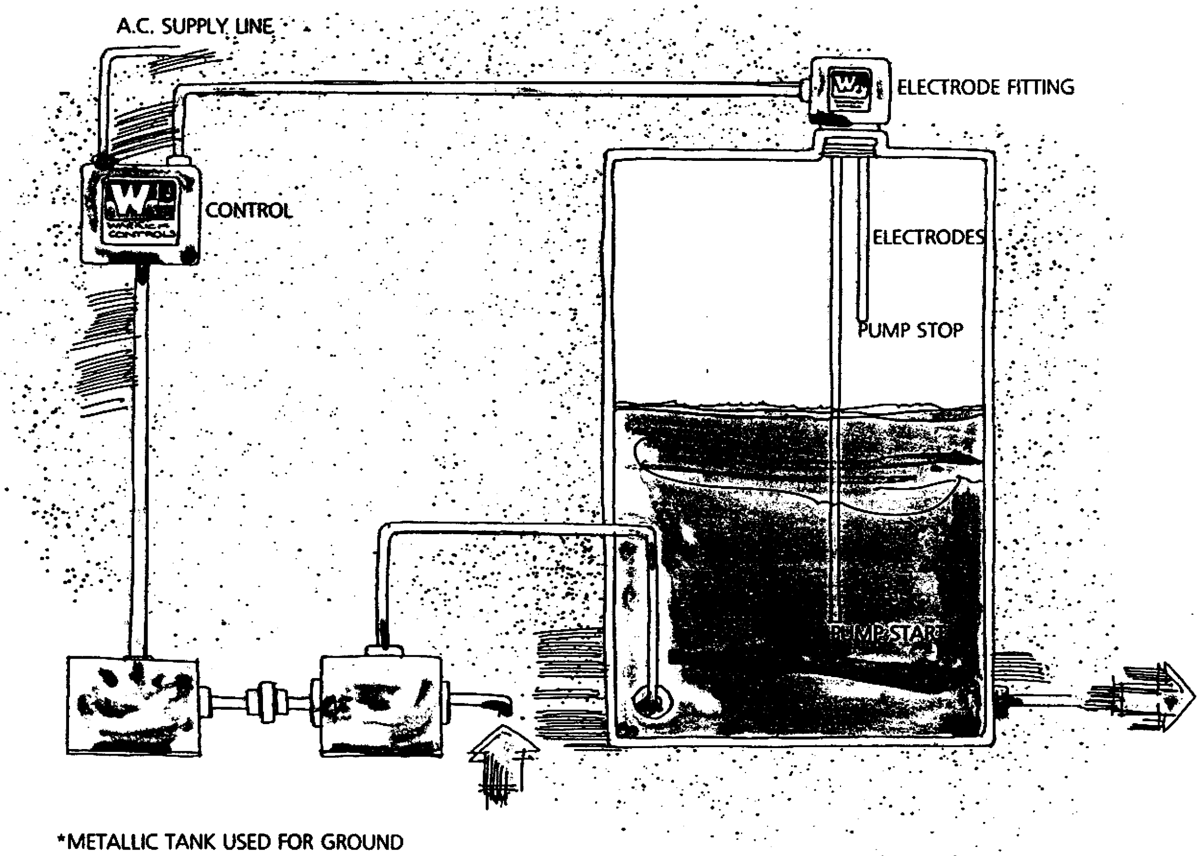
Electrodes of ¼" rod are typically used when electrode lengths do not exceed eight feet. Wire-suspended electrodes, short metallic bars mechanically connected to the fitting with insulated wire, are recommended in applications where electrode length exceeds eight feet.

The electrode fitting is generally mounted on top of the vessel and performs several functions:

- Mechanically supports the electrodes.
- Insulates the electrodes from the vessel wall.
- Provides terminals which accommodate wiring from the control.

Electrode fittings are provided in a variety of designs, pressure and temperature ratings, materials, etc.

A control rounds out the typical Warrick system. It is an electrical device equipped with contacts which open and close in response to liquid levels sensed by the tips of the electrodes. Controls are available in varying designs and sensitivity ratings to accommodate a variety of application requirements.



*METALLIC TANK USED FOR GROUND

The drawing illustrates a typical control system installation handling a pump up operation. In this arrangement the pump starts at a low level and stops at a higher level for the purpose of replenishing liquid drawn from the vessel. Although the level varies, it is always maintained within the limits established by the tips of the two electrodes. A pump down operation is similar. However, the pump starts at a high level and stops at a low level in order to remove liquid which is entering the vessel from some source.

Principles of operation.

The type of control mechanism (solid state or electromechanical) does not change the basic *function* of a level control system. Both convert a small electrical current to mechanical motion. For example, the typical conductance-actuated level control system illustrated on page 8 could accommodate either a solid state or electromechanical control.

Solid state controls have certain advantages over electromechanical units. In addition, the conditions of some applications make solid state controls more desirable and appropriate.

Warrick Controls has designed and developed several solid state controls. Today, a full range of these units is available for virtually any OEM or end-user application.

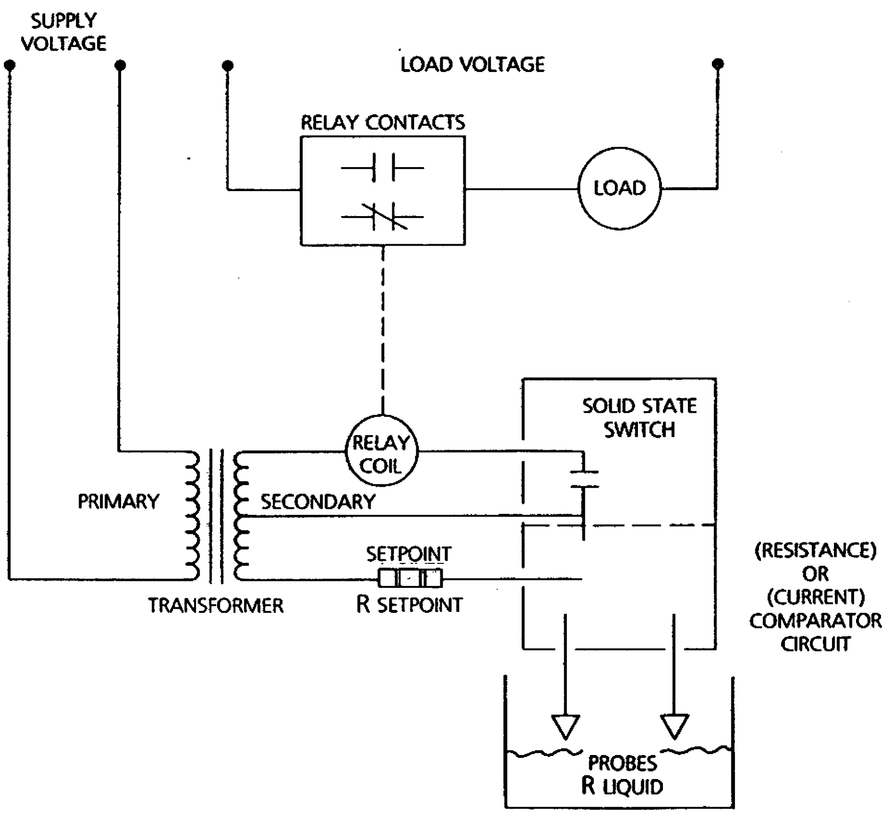
Solid state controls.

Solid state controls employ what amounts to a switch within a switch. Separate secondary circuits are used to 1) sense current flow in the liquid and compare it to the current flow through a fixed set point resistor and 2) energize the relay.

When the current of the sensing circuit exceeds that of the fixed resistor, the circuit activates a solid state switch which allows current to flow through the relay coil. Hence, the "switch within a switch." Since higher voltages are not necessary to push the current through both the liquid and the relay coil, solid state controls can function with much lower probe voltages.

Low voltage solid state components offer greater safety where exposed electrodes pose a shock hazard. They also have fewer moving parts and can be used with a greater range of liquids—even those of slight conductivity. An added advantage of solid state controls is the ability to operate in inverse mode, providing fail-safe operation.

The operation described above is for a direct mode control. Inverse mode operation is the opposite—the control will energize (contacts change state from shelf position) immediately when power is applied to the control and no liquid is present on the electrodes. The control will then de-energize when the liquid level increases to the electrodes. Each specific application dictates the type of contact and mode of operation required to provide fail-safe operation.



Principles of operation.

Electromechanical Controls.

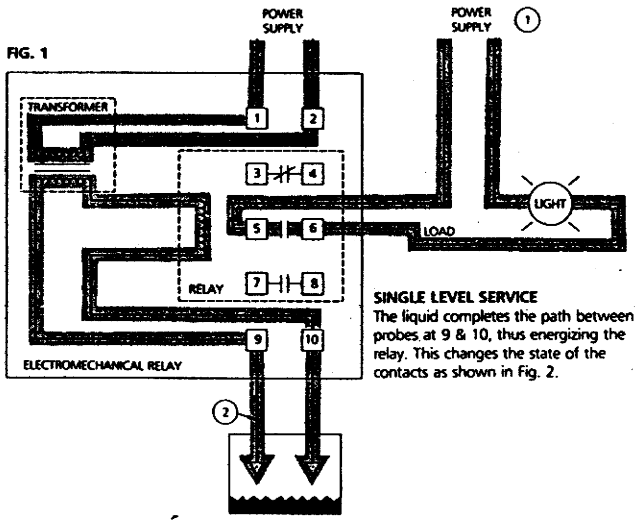
As with solid state controls, electromechanical units convert electrical current to mechanical motion. A transformer and relay are connected to one or more insulated electrodes positioned to contact the liquid at a predetermined level, activating (opening or closing) the relay contacts.

In electromechanical systems, the electrode circuit is a simple series circuit including the transformer secondary coil, relay coil, two electrodes, and liquid. When the liquid is below the electrode tip, the electrode circuit is open. No current flows in the circuit so the relay coil is de-energized. When the liquid reaches the electrode tip, the electrodé circuit is closed via an electrically conductive path through the liquid. The relay coil is energized and the relay contacts transfer position.

This arrangement is called a single level service because the contacts transfer position at the same single elevation for both rising and lowering levels. While this is satisfactory for many uses, it is unsuitable for pumping applications. In a pumping application it is desirable to start the pump at one level and stop it at another level. This type of operation is known as differential level service because the contacts transfer position at one elevation as the level rises and then transfer again at a lower, different elevation as the level recedes.

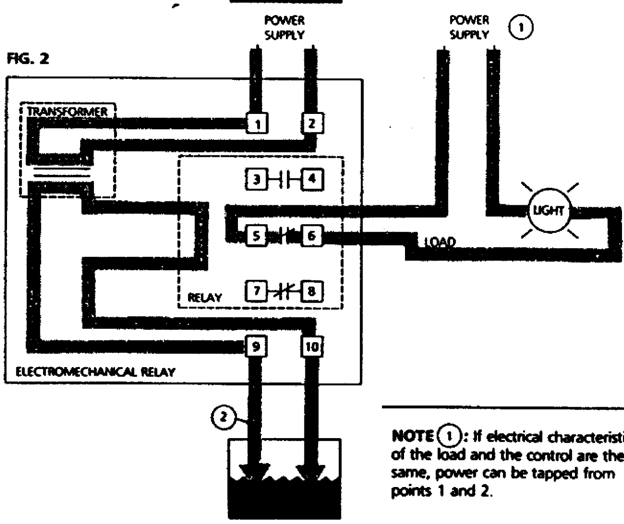
SINGLE LEVEL SERVICE

FIG. 1



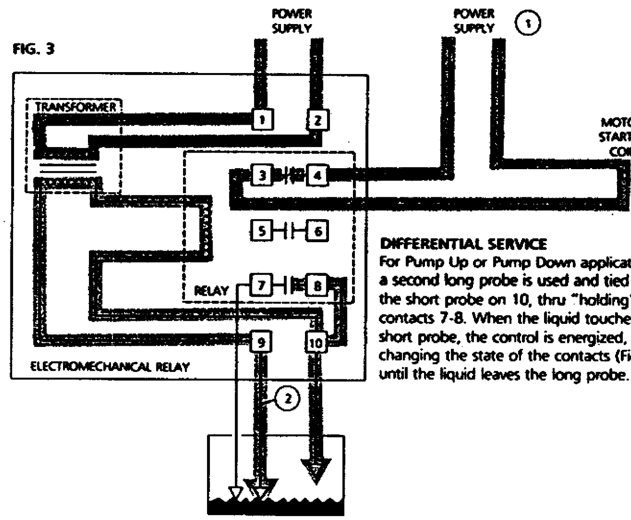
SINGLE LEVEL SERVICE
The liquid completes the path between probes at 9 & 10, thus energizing the relay. This changes the state of the contacts as shown in Fig. 2.

FIG. 2



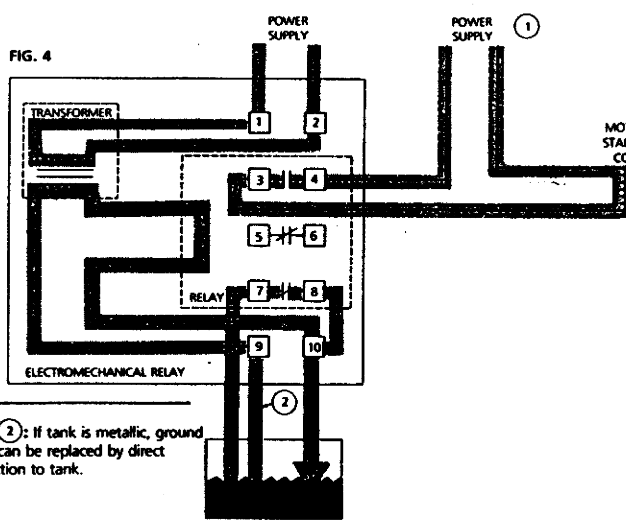
DIFFERENTIAL SERVICE

FIG. 3



DIFFERENTIAL SERVICE
For Pump Up or Pump Down applications, a second long probe is used and tied to the short probe on 10, thru "holding" contacts 7-8. When the liquid touches the short probe, the control is energized, thus changing the state of the contacts (Fig. 4), until the liquid leaves the long probe.

FIG. 4



NOTE ①: If electrical characteristics of the load and the control are the same, power can be tapped from points 1 and 2.

NOTE ②: If tank is metallic, ground probe can be replaced by direct connection to tank.

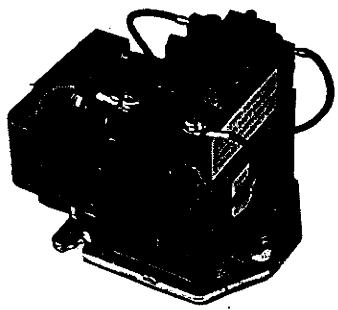
Current Flowing
Voltage Potential But No Current Flow
Water

Solid state—triac output. (continued)

Table 17-1

	Design	Contact Design	Contact Rating at 110 VAC	Mode of Operation	Sensitivity	Prim. Volt. VAC	Secondary Voltage VAC	Listing	Connections	Options and Adjustments	Ordering Information (Page)
Series 19	Solid state circuit and switch	[illegible]	⅓ H.P. or 1 H.P.	[illegible]	0-19K OHM factory set	[illegible]	10V	[illegible]	All spade type conn.	[illegible]	27

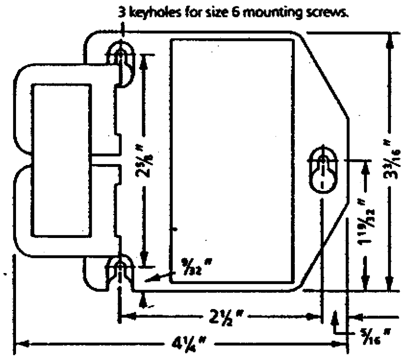
Electromechanical



Series 1. Simple and inexpensive, Series 1 controls are industrial type, low sensitivity, two and three pole electromechanical controls with high contact ratings. They are suitable for solutions of less than 20,000 ohm-centimeters specific resistance. U.L. listed as a "Limit Control."

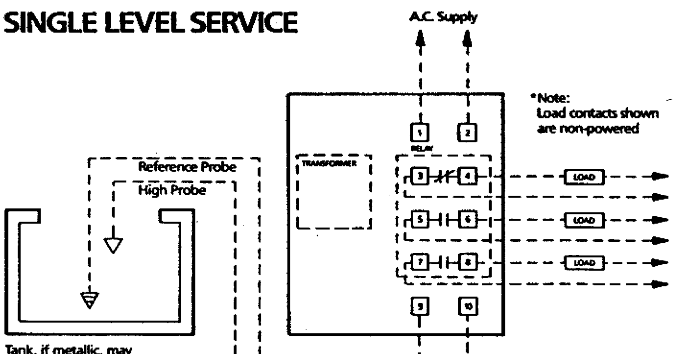
CAUTION: If personnel can come in contact with electrodes, the Series 1 control should not be used. Use controls with low secondary voltages (probe voltages under 25 V).

***NOTE: Series 1 control not recommended for interfacing to microprocessor-based systems.**



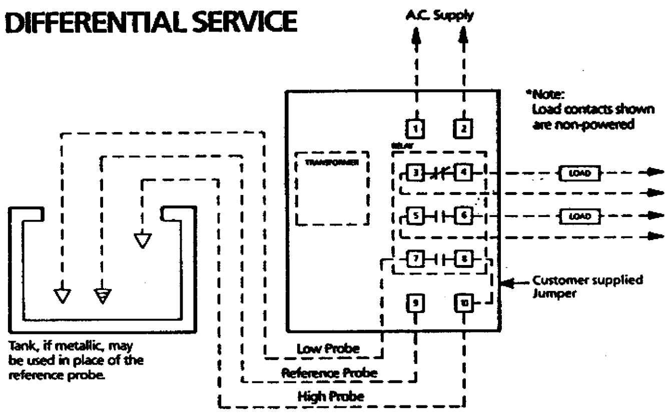
Overall height of control = 3³⁄₁₆"

SINGLE LEVEL SERVICE



Tank, if metallic, may be used in place of the reference probe.

DIFFERENTIAL SERVICE

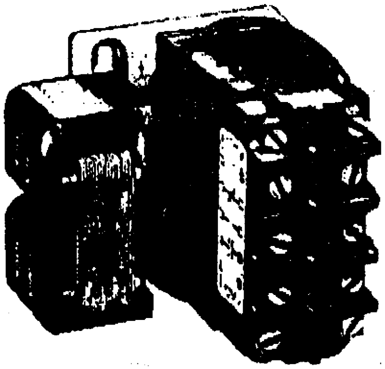


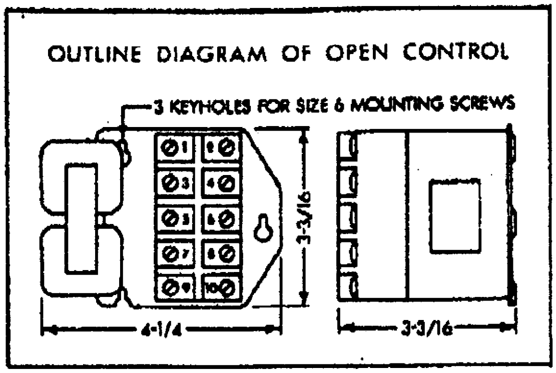
Tank, if metallic, may be used in place of the reference probe.

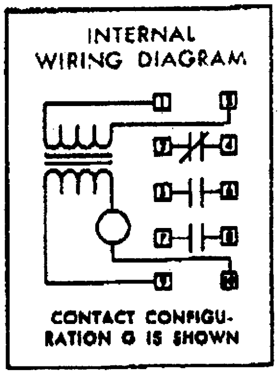
Table 17-2

	Design	Contact Design	Contact Rating at 110 VAC	Mode of Operation	Sensitivity	Prim. Volt. VAC	Secondary Voltage VAC	Listing	Connections	Options and Adjustments	Ordering Information (Page)
Series 1	Electro-mechanical	[illegible]	16 AMP Resistive 1 H.P.	[illegible]	0-20 K OHM field adj.	[illegible]	25V 75V 150V 300V 500V	[illegible]	All screw type conn.	[illegible]	25

SERIES 1 CONTROLS







GENERAL

Series 1 controls are simple, inexpensive, industrial type, low sensitivity, two and three pole, transformer/relay combinations with high contact ratings. They are suitable for use with acids and alkalis, brine, ordinary and carbonated water, process steam condensate, sewage, industrial wastes, and other solutions of less than 20,000 ohm-centimeters specific resistance. The controls are generally intended to be used with electrodes which are mounted inside closed vessels. Do not use Series 1 controls if the electrodes are exposed to personal contact and/or situated in a potentially explosive atmosphere. Use Series 2 controls in the former case, Series 7 controls in the latter case.

SPECIFICATIONS

Baseplate: High strength, diecast, aluminum alloy. Three dimpled keyholes for size 6 mounting screws.

Coils: Wound on nylon bobbins. Epoxy encapsulated.

Contact Design: 2PST and 3PST bridge type double break in all possible combinations of normally open and normally closed. Fully enclosed. Buttons are 1/4 inch diameter silver cadmium oxide.

Contact Ratings: (a) Current: 16 amperes at 115 volts A.C. and 8 amperes at 230 volts A.C., (b) Horsepower: 1 horsepower at 115 and 230 volts A.C., (c) Pilot duty: 775 volt-amperes at 115 and 230 volts A.C. and 250 volt-amperes at 460 volts A.C.

Identification: By the use of a component number on a data label affixed to the control. See component number formula on lower portion of page 8.

Mode of Operation: Direct only. Contacts assume normal positions with open electrode circuit. Normally open contacts close and normally closed contacts open with closed electrode circuit. See diagrams relating contact action to liquid level on pages 9 and 10.

Molded Structural Parts: High mechanical and dielectric strength, dimensionally stable, arc resistant, thermosetting phenolic.

Primary (A.C. Supply Line): (a) Voltages: 115, 230, 460 and 575 nominal, plus 10% minus 15%, (b) Frequency: 50/60 Hertz, (c) Power: 4 watts with short circuited electrode circuit, (d) Volt-amperes: 15 volt-amperes with short circuited electrode circuit.

Secondary (In Electrode Circuit): (a) Voltages: 25, 75, 150, 300 and 500 volts A.C. RMS nominal with open circuited electrode circuit, (b) Volt-amperes: 6 volt-amperes with short circuited electrode circuit.

Sensitivity: See table at bottom of right hand column.

Shunt Capacitance Tolerance: The maximum allowable distributed capacitance placed across terminal pair 9-10 by the control-to-electrode(s) conductor(s) and ground is related to the secondary voltage as follows: 4.0 mfd at 25 volts, 0.4 mfd at 75 volts, 0.1 mfd at 150 volts, 0.025 mfd at 300 volts and 0.0075 mfd at 500 volts. With thermoplastic insulated wires in dry metallic conduit the limiting control-to-electrode(s) distances are as follows for differential level service applications: 75,000 feet at 25 volts, 7,500 feet at 75 volts, 1,750 feet at 150 volts, 300 feet at 300 volts, and 150 feet at 500 volts. Those distances may be doubled for single level service applications.

Spacings: For 600 volts. 1/2 inch creepage across surfaces. 3/8 inch through air.

Temperature: Minus 30 to plus 130 degrees F. ambient.

Terminals: Size 8 pan head screws with captivated wire clamping plate. Numbered 1 to 10 for identification. Located on front of control for accessibility.

U/L and CSA: See U/L Guide Nos. 167 E7 and MBPR2, File MP1430. See CSA Guide 184-N-13.90, File 11644.

SECONDARY VOLTAGES FOR VARIOUS LIQUIDS

★ LIQUID	• SENSITIVITY IN OHMS	SECONDARY VOLTAGE
Metallic circuits.	50	25
Brine, milk, cleaning and plating solutions. Sea water.	450	75
Concentrated and dilute acids and alkalis.	1,500	150
Medium and hard water from lakes, rivers, storm runoff, wells and municipal water systems. Water soluble oils. Sewage. Industrial wastes.	7,000	300
Soft water from wells. Process steam condensate.	20,000	500

★ Inquire for secondary voltages of unlisted liquids.

• For liquids of known specific resistance use a control with that secondary voltage which provides a sensitivity, in ohms, greater than and closest to the specific resistance, in ohm-centimeters.

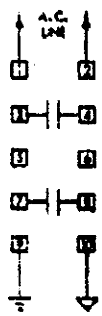
SERIES 1 CONTROLS

2 N.O. CONTACTS — CONTACT CONFIGURATION C

DIAGRAM C1

SINGLE LEVEL SERVICE

HIGH LEVEL ALARM OR LOW LEVEL CUTOFF

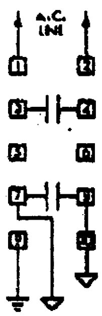


CONTACT OPERATION
Load contacts 3-4 and 7-8 close when the level rises to the electrode. They open when the level recedes below the electrode.

DIAGRAM C2

DIFFERENTIAL LEVEL SERVICE

PUMP DOWN

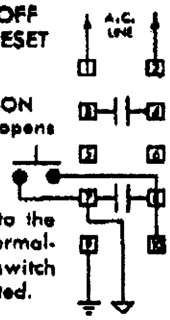


CONTACT OPERATION
Load contact 3-4 closes when the level rises to the short electrode connected to terminal 10. It opens when the level recedes below the long electrode connected to terminal 7.

DIAGRAM C3

LOW LEVEL LOCKOUT SERVICE

LOW LEVEL CUTOFF WITH MANUAL RESET

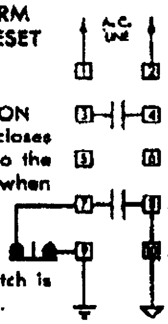


CONTACT OPERATION
Load contact 3-4 opens when the level recedes below the electrode. It closes when the level rises to the electrode AND the normally open pushbutton switch is momentarily actuated.

DIAGRAM C4

HIGH LEVEL LOCKIN SERVICE

HIGH LEVEL ALARM WITH MANUAL RESET



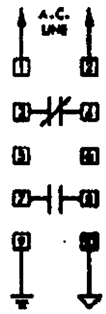
CONTACT OPERATION
Load contact 3-4 closes when the level rises to the electrode. It opens when the level recedes below the electrode AND the normally closed pushbutton switch is momentarily actuated.

1 N.C. & 1 N.O. CONTACTS — CONTACT CONFIGURATION D

DIAGRAM D1

SINGLE LEVEL SERVICE

HIGH OR LOW LEVEL CUTOFF AND ALARM

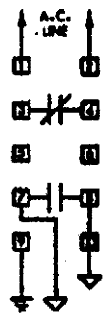


CONTACT OPERATION
Load contact 3-4 opens and load contact 7-8 closes when the level rises to the electrode. Contact 3-4 closes and contact 7-8 opens when the level recedes below the electrode.

DIAGRAM D2

DIFFERENTIAL LEVEL SERVICE

PUMP UP

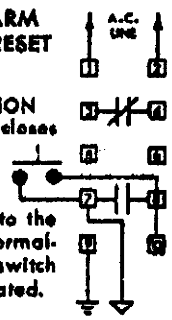


CONTACT OPERATION
Load contact 3-4 opens when the level rises to the short electrode connected to terminal 10. It closes when the level recedes below the long electrode connected to terminal 7.

DIAGRAM D3

LOW LEVEL LOCKOUT SERVICE

LOW LEVEL ALARM WITH MANUAL RESET

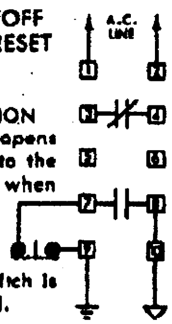


CONTACT OPERATION
Load contact 3-4 closes when the level recedes below the electrode. It opens when the level rises to the electrode AND the normally open pushbutton switch is momentarily actuated.

DIAGRAM D4

HIGH LEVEL LOCKIN SERVICE

HIGH LEVEL CUTOFF WITH MANUAL RESET



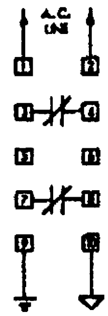
CONTACT OPERATION
Load contact 3-4 opens when the level rises to the electrode. It closes when the level recedes below the electrode AND the normally closed pushbutton switch is momentarily actuated.

2 N.C. CONTACTS — CONTACT CONFIGURATION E

DIAGRAM E1

SINGLE LEVEL SERVICE

HIGH LEVEL CUTOFF OR LOW LEVEL ALARM



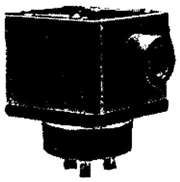
CONTACT OPERATION
Load contacts 3-4 and 7-8 open when the level rises to the electrode. They close when the level recedes below the electrode.

There is no diagram for differential level service for controls with only two normally closed contacts because the control does not possess the normally open contact required to seal the electrode circuit.

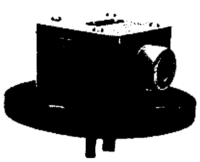
There is no diagram for low level lockout service for controls with only two normally closed contacts because the control does not possess the normally open contact required to seal the electrode circuit.

There is no diagram for high level lockin service for controls with only two normally closed contacts because the control does not possess the normally open contact required to seal the electrode circuit.

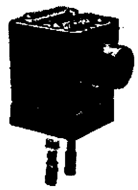
General-purpose multi-probe fittings.



Series 3E. The electrode fittings in Series 3E are general-purpose, cast metal, pressure-tight assemblies sized to accommodate from one to seven electrodes and equipped with external pipe threads for attachment to the vessel.



Series 3F. Series 3F electrode fittings are general purpose, flanged, pressure-tight assemblies sized to accommodate from one to seven electrodes. They mate with standard pipe flanges coupled to the top of the vessel.



Series 3N. Series 3N fittings are inexpensive, general-purpose assemblies which accommodate one to three electrodes and mount on a flat surface on the top of open tanks or closed vessels operating at atmospheric pressure. Various body materials qualify them for use on water and diluted corrosive liquids.

Table 21-1 General Purpose Multiple Probe Fittings

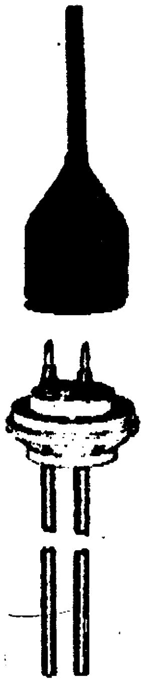
Series	Type of connection	Probes/ Electrodes	Terminal Housing	Wetted Material	Pressure/ temperature	Listing	Catalog information (Page)
3EXX	Threaded	1 thru 7 C.I.—3B3A R.B.—3B3A SS—3B1B	Die-cast Aluminum, Epoxy coated	Cast iron Red brass 316 SS	125 psig 353°F 250 psig 406°F 250 psig 406°F	UL Rec. CSA FM	[illegible]
3FXX	Flanged	1 thru 7 C.I.—3B3A R.B.—3B3A 1018—3B3A 316—3B1B PVC—3P017	Die-cast Aluminum, Epoxy coated	Cast iron Red brass 316 SS 1018 C.S. PVC	125 psig 353°F 225 psig [illegible] 230 psig [illegible] 275 psig [illegible] 200 psig 75°F	CSA	[illegible]
3NXX	Bracket	1 thru 3 PVC—3P017 R.B.—3P017 316—3P018	Die-cast Aluminum, Epoxy coated	PVC Red brass 316 SS	0 psig [illegible] 0 psig 500°F 0 psig 500°F	CSA	[illegible]

Chart 21-1 Dimensions

	Attachment To Vessel					
	3E	3F		3N		
No. of Probes	NPT	Nominal Pipe Flange Size	Diameter of Flange		Conduit Boss Thread Size Series 3E, 3F and 3N	Terminal Housing Size Series 3E, 3F and 3N W x D x H
1	1-11½	1	[illegible]	2¼" square flat pad 1½" dia. hole in top of vessel secured w/#10 machine screws at the corners of a 1½" square	[illegible]	2¼ x 2¼ x 2¼
2	2-11½	2	6		[illegible]	3¼ x 3¼ x 2⅜
3	2-11½	2	6		[illegible]	3¼ x 3¼ x 2⅜
4	2½-8	2½	7	Not available with 4-7 probes	[illegible]	3¼ x 3¼ x 2⅜
5	3-8	3	7½		[illegible]	4 x 4 x 2½
6	3-8	3	7½		[illegible]	4 x 4 x2½
7	3-8	3	7½		[illegible]	4 x 4 x2½

SERIES 3M AND 3N ELECTRODE FITTINGS

SERIES 3M ELECTRODE FITTINGS



Upper and lower assemblies shown disconnected

GENERAL

Series 3M electrode fittings are two-piece assemblies, complete with one to four electrodes, intended for use in dairy, drug and pharmaceutical, and food and drink applications where cleanliness is paramount. Design permits rapid removal of the fitting from the vessel for cleaning and sterilization.

SPECIFICATIONS

Attachment to Vessel: Choice of body contours for standard 45° bevel, Ladish "Tri-Clamp" and Cherry-Burrell "Quick-Clamp" 2 inch sanitary ferrules.

Body Material: Type 66 nylon.

CSA: File 11644, Guide 184-N-13.90.

Cable Length: Standard is 10 feet.

Design: Upper and lower mating assemblies. The lower assembly consists of the body, electrodes and allied banana plugs. The upper assembly is a cable and polarized receptacle which accommodates the plugs on the lower assembly. A flexible lip on the receptacle tightly clasps a boss on the body to provide a watertight seal.

Electrodes: Choice of fittings with one to four, 1/4 inch diameter, polished, type 316 stainless steel electrodes in standard lengths of one, two or three feet. Electrode lengths referenced to the bottom of the body. Electrodes easily trimmed to exact, desired lengths.

Food and Drug Administration: All materials exposed to contents of the vessel are FDA approved. The two assemblies can be disconnected, and the lower assembly removed from the ferrule, in a few seconds for cleaning and sterilization. Can be autoclaved at 15 psig saturated steam (250°F.) without degradation.

Identification: By the use of a component number which establishes the number and length of the electrodes and defines the character of the body contour.

Pressure/Temperature Limits: 150 psig @ 150°F.

ORDER BY COMPONENT NUMBER

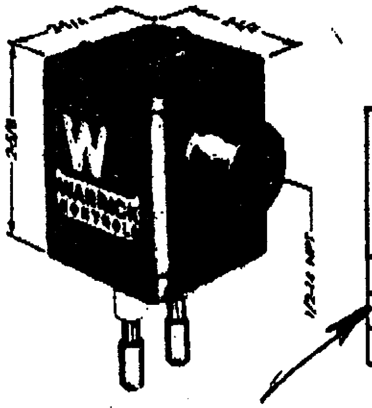
3MXXX

3RD PLACE SYMBOL	Number Of Electrodes
1	One
2	Two
3	Three
4	Four

4TH PLACE SYMBOL	Electrode Lengths (Feet)
A	One
B	Two
C	Three

5TH PLACE SYMBOL	Body Contour (2" Size)
1	45° Bevel
2	Tri-Clamp
3	Quick-Clamp

SERIES 3N ELECTRODE FITTINGS



GENERAL

Series 3N fittings are inexpensive, general purpose assemblies which accommodate one to three electrodes and mount on a flat surface on the top of open tanks or closed vessels operating at atmospheric pressure. Various body materials qualify them for use on water and corrosive liquids.

SPECIFICATIONS

Attachment to Vessel: Requires a 2-1/4 inch square flat pad or surface on, and a 1-1/2 inch diameter hole in, the top of the vessel. Secured with size 10 machine screws at the corners of a 1-1/2 inch square.

Body Materials: Choice of polyvinyl chloride, leaded red brass or 316 stainless steel body.

CSA: See CSA File 11644, Guide 184-N-13.90.

Electrodes Accommodated: Choice of fittings for one to three electrodes. Directly accepts 1/4 inch diameter, rod type, Series R electrodes. With 3Z1B adapters, accepts wire suspended, Series 3W electrodes.

ORDER BY COMPONENT NUMBER

3NXX

3RD PLACE SYMBOL	Number Of Electrodes Accommodated
1	One
2	Two
3	Three

4TH PLACE SYMBOL	Body Material
A	PVC
B	Red Brass
C	316 SS

Identification: By the use of a component number which establishes the body material and number of electrodes accommodated. See component number formula.

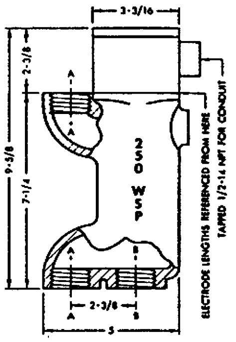
Insulation Sleeves: Type TFE teflon.

Pressure/Temperature Limits: (a) With polyvinyl chloride body: 0 psig @ 150°F. (b) With red brass or stainless steel body: 0 psig @ 500°F. A vaportight seal is achieved between the fitting and vessel by employing the gasket supplied with the fitting.

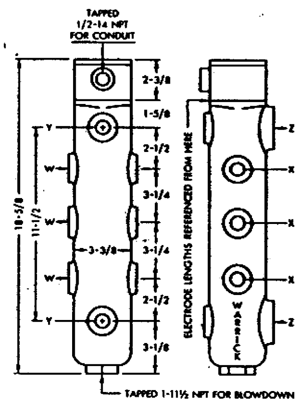
Terminal Housing: Diecast aluminum with epoxy coat. Nema-1 to 5 integrity. 1/2-14 NPT boss for conduit.

Specialty Fittings.

Side chamber fittings.



Series 3C. These electrode fittings are cast iron, pressure-tight chambers containing one to four electrodes and are provided with pipe tappings for connection to the side of boilers, hydropneumatic tanks and pressure vessels so the level in the chamber duplicates the level in the vessel.



Series 3K. Electrode fittings in this series are cast iron, pressure-tight chambers containing one to four electrodes and are provided with pipe tappings for connection to the side of boilers, steam generators and pressure vessels so the level in the chamber duplicates the level in the vessel. Additional tappings accommodate tricocks and gauge glass fittings.

Table 22-1 Side Chamber Fittings

Series	No. of Electrodes	Body Material	Pressure/Temp.	Electrode Length	Listing	Ordering Information (Page)
3CXXX	[illegible]	Cast iron Red brass	[illegible]	½ inch to 6 inches	[illegible]	29
3KXXXX	[illegible]	Cast iron	[illegible] 406°F (Sat. steam)	1¾ inch to 13 inches	[illegible] CSA FM	30

Sanitary fittings. (Food Industry)

Series 3M. Series 3M electrode fittings are two-piece assemblies, complete with one to four electrodes, intended for use in dairy, drug and pharmaceutical and food and drink applications where cleanliness is paramount. Design permits rapid removal of the fitting from the vessel for cleaning and sterilization.

Table 22-2 Sanitary Fittings and Electrodes (Food Industry)

Series	No. of Electrodes	Body Contour	Body Material	Probe Material	Listing	Pressure/Temp.	Ordering Information (Page)
3MXXX	[illegible]	45° bevel tri-clamp quick clamp	Type 66 Nylon	316 SS	FDA approved materials CSA	150 psig 150°F	[illegible]

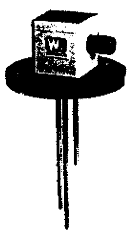
Multiple wire-suspended fittings.

Series 3U. Inexpensive Condulet-style assemblies designed for use with wire-suspended electrodes can be mounted on end of conduit over open sumps, open tanks, ponds and reservoirs. Available in PVC or cast iron body, ½", ¾" or 1" conduit connections, 1-10 electrodes depending on conduit connection.

Table 22-3 Multiple Wire-Suspended Electrode Fittings

Series	No. of Electrodes	Body Material	Conduit Size	Pressure/Temp.	Literature	Ordering Information (Page)
3UXX	[illegible]	PVC Cast iron	[illegible]	0 psig 150°F	[illegible]	31

Corrosion-resistant multi-probe fittings.



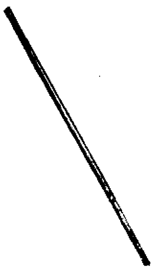
Series 3G. Designed for use in corrosive applications. Flanged assemblies sized to accommodate from one to seven electrodes and to mate with standard flanges on vessel top. Plate mounting is also available. PVC bases with polycarbonate housings (¾" NPT PVC conduit hub).

Table 22-4 Corrosion-Resistant Multi-Probe Fittings

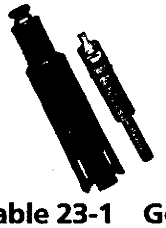
Series	Mounting Style	No. of Electrodes	Electrode Style	Base Material	Housing Material	Literature	Ordering Information (Page)
3GXXX	[illegible]	1 thru 4 (2" flg.) 1 thru 7 (3" flg.) 1 thru 7 (3", 6" plate)	[illegible]	PVC	[illegible]	B5350D—B5358D	[illegible]

Electrodes.

General application electrodes.



Series 3R. These electrodes are metallic rods with one end threaded so they can be screwed into the couplings on electrode fittings to extend vertically down into the liquid. They are available in a variety of materials to satisfy the requirements of water and many corrosive solutions. Series 3T, tapered electrode, used in conjunction with fitting 3G.



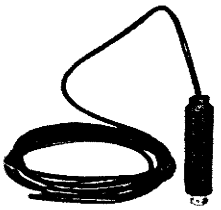
Series 3W. Series 3W electrodes are metallic bars contained within a protective plastic shield. They are suspended above the liquid by the use of PVC-insulated wires. ⅞" dia. x 3¾" in length.

Table 23-1 General Application Electrodes

Series	Style	Material	Sheathing	Ordering Information (Page)
3RXXXX 3TXXXX	¼" rod (threaded) ¼" rod (tapered)	Brass 303 SS 316 SS Carp. 20 Hast. B Hast. C Monel Titanium	PVC (200°F) Teflon (500°F) Silicon/ Heat Shrink	31
3WX*	Wire Suspended	Brass 303 SS	Polyethylene Shield PVC coated wire (150°F)	31

*To attach 3W to 3E, 3F or 3N fittings, 3Z1A wire and a 3Z1B adapter kit are required. One adapter required for each electrode.

Corrosion-resistant electrode.



Series 3Y. Corrosion-resistant metallic bars within a protective plastic shield designed for use in corrosive liquid applications. Suspension wire is PVC-jacketed and is attached to the electrode at the factory. ⅞" dia. x 3½" in length.

Table 23-2 Corrosion-Resistant Electrode

Series	Style	Tip Material	Shield Material	Ordering Information (Page)
3YXXX	Wire Suspended	Carp. 20 Hast. B Hast. C 316 SS	PVC (150°F)	31

Chart 23-3 Sensitivity-Material Selection

	Sensitivity-Conductivity		Electrode Material	
Liquid Or Material	Ohms/cm	Micro-Mhos/cm	Good*	Better**
†Acids	Consult Factory		Consult Factory	
Aluminum Hydroxide	2.2K	450	316 SS	Titan.
Aluminum Sulfate	2.2K	450	303 SS	Hast. C
Ammonia	5K	200	316 SS	N.A.
Ammonium Chloride	1K	1K	316 SS	Titan.
Ammonium Hydroxide	10K	100	316 SS	Titan.
Ammonium Nitrate	18K	50	303 SS	316 SS
Ammonium Sulfate	10K	100	316 SS	Titan.
Baby Foods	1K	1K	303 SS	316 SS
Barium Chloride	1K	1K	Carp. 20	N.A.
Barium Nitrate	1K	1K	316 SS	N.A.
Beer	2.2K	450	303 SS	316 SS
Black Liquor	1K	1K	Consult Factory	
Borax—Aqueous	10K	100	Brass	303 SS
Bourbon	200K	5	N.A.	316 SS
Brine	1K	1K	N.A.	Hast. C
Buttermilk	1K	1K	N.A.	316 SS
Cadmium Chloride	1K	1K	316 SS	N.A.
Cadmium Nitrate	1K	1K	316 SS	N.A.
Cake Batter	5K	200	303 SS	316 SS
Calcium Chloride	1K	1K	Carp. 20	Hast. C
Calcium Hydroxide	10K	100	316 SS	Titan.
Catsup	2.2K	450	303 SS	316 SS
Caustic Soda	1K	1K	316 SS	Hast. B
Cement Slurry	5K	200	303 SS	316 SS
Coffee	2.2K	450	303 SS	316 SS
Corn Syrup	45K	21	303 SS	316 SS
Corn—Cream Style	2.2K	450	303 SS	316 SS
Ferric Chloride	10K	100	N.A.	Titan.
Ferrous Sulfate	10K	100	Carp. 20	Titan.
Ink (Water Base)	2.2K	450	N.A.	316 SS
Jams/Jellies	45K	21	303 SS	316 SS
Juices—Fruit/Vegetable	1K	1K	303 SS	316 SS
Lithium Chloride	1K	1K	N.A.	Carp. 20
Magnesium Chloride	1K	1K	316 SS	Carp. 20
Magnesium Hydroxide	2.2K	450	316 SS	N.A.
Mayonnaise	5K	200	303 SS	316 SS
Mercuric Chloride	90K	11	N.A.	Titan.
Milk	1K	1K	303 SS	316 SS
Molasses	10K	100	303 SS	316 SS
Mustard	1K	1K	303 SS	316 SS
Oil—Soluble	10K	100	N.A.	303 SS
Paper Stock	5K	200	Titan.	N.A.
Photographic Solutions	1K	1K	316 SS	Hast. C
Plating Solutions	2.2K	450	N.A.	316 SS
Potassium Chloride	1K	1K	316 SS	Titan.
Salts—Chemical	2.2K	450	Monel	N.A.
Sewage	5K	200	303 SS	316 SS
Silver Nitrate	1K	1K	316 SS	Carp. 20
Soap Foam	18K	50	303 SS	316 SS
Sodium Carbonate	2.2K	450	316 SS	Monel
Sodium Hydroxide	1K	1K	316 SS	Hast. B
Soups	1K	1K	303 SS	316 SS
Starch Solutions	5K	200	303 SS	316 SS
Sugar Solutions	90K	11	303 SS	316 SS
Vinegar—Aqueous	2.2K	450	316 SS	Carp. 20
Water—Carbonated	3K	330	303 SS	316 SS
Water—Condensate	18K	50	Brass	303 SS
Water—Chlorinated	5K	200	316 SS	Monel
Water—Distilled	450K	2	Brass	303 SS
Water—Deionized	2.0M	.5	Brass	303 SS
Water—Hard/Natural	5K	200	Brass	303 SS
Water—Salt	2.2K	450	Monel	N.A.
Wine	2.2K	450	303 SS	316 SS
Zinc Chloride	1K	1K	Carp. 20	Titan.
Zinc Sulfate	2.2K	450	316 SS	Titan.

*Less than .020" erosion per year.

**Less than .002" erosion per year.

†Note: Liquid concentration and temperature will affect conductivity and material erosion rate. Contact factory for detailed information.

N.A.—No material available with this erosion rate.

SERIES 3R AND 3W ELECTRODES

The two basic series of electrodes which are mated with Series 3A, 3B, 3E, 3F and 3N electrode fittings are presented below. Series 3R, rod type electrodes are employed with each of those fittings. Series 3W, wire suspended electrodes are employed in lieu of Series 3R electrodes only with Series 3E, 3F and 3N fittings under certain conditions. Electrodes are not ordered separately for Series 3C, 3H, 3K or 3M fittings because those fittings are supplied complete with factory installed electrodes identified in component number formulas.

SERIES 3R ELECTRODES

GENERAL

Series 3R electrodes are metallic rods with one end threaded so they can be screwed into the couplings on electrode fittings to extend vertically down into the liquid. They are available in a variety of materials to satisfy the requirements of water and many corrosive solutions.

SPECIFICATIONS

Application: Employ with Series 3A, 3B, 3E, 3F and 3N electrode fittings for water and corrosive solutions. Use bare electrodes, without sheathing, for lengths up to three feet. It is recommended that all electrodes longer than three feet be sheathed when (a) multiple electrodes are supported in a Series 3E, 3F or 3N fitting, or (b) individual electrodes are supported in two or more Series 3A or 3B fittings positioned closely together. The sheathing precludes electrical contact between electrodes which may mechanically touch one another.

Corrosion Resistance: The following metals are the best for the indicated solutions. (a) Brass: Soft water and condensate, (b) 303 Stainless Steel: Hard water and sewage, (c) 316 Stainless Steel: Cyclohexylamine, and food and drink products, (d) Carpenter 20: Nitric and sulfuric acids, (e) Hastelloy B: Hydrochloric acid, (f) Hastelloy C: Acetic and chromic acids; calcium hydroxide; calcium, potassium and sodium hypochlorites, (g) Monel: Sea water, potassium and sodium hydroxides. Polyvinyl chloride sheathing is adequate for all types of water and food and drink products. Use teflon sheathing for other solutions. Warrick will recommend suitable electrode materials for specific solutions when the chemical character, concentration and temperature of the solution are indicated.

Dimensions: Bare electrodes are 1/4 inch diameter. Sheathed electrodes are 5/16 inch diameter. Choice of standard lengths in integral feet. Electrodes of brass, stainless steel, Carpenter 20 and monel easily trimmed to exact lengths. Due to the difficulty of cutting Hastelloy B and C electrodes, Warrick will supply electrodes of those materials cut to any desired specified lengths.

Identification: By the use of a component number which establishes the length, electrode material and sheathing material, if any.

Materials: See 4th and 5th place symbol tables. Polyvinyl chloride sheathing limited to 200°F. Teflon sheathing limited to 500°F.

ORDER BY COMPONENT NUMBER

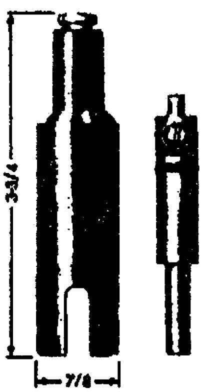
3RXXX

3RD PLACE SYMBOL	Length (Feet)
1	One
2	Two
3	Three
4	Four
5	Five
6	Six
Et Cetera	

4TH PLACE SYMBOL	Electrode Material
A	Brass
B	303 SS
C	316 SS
D	Carp. 20
E	Hast. B
F	Hast. C
G	Monel

5TH PLACE SYMBOL	Sheath Material
0	None
1	PVC
2	Teflon

SERIES 3W ELECTRODES



ORDER BY COMPONENT NUMBER

3WX

3RD PLACE SYMBOL	Electrode Material
1	Brass
2	303 SS

GENERAL

Series 3W electrodes are metallic bars contained within a protective plastic shield. They are suspended from above the liquid by the use of insulated wires.

SPECIFICATIONS

Accessories: Use type 3Z1A suspension wire for supporting the electrodes. Use type 3Z1B adapters for fastening the upper end of suspension wires to the couplings of electrode fittings. One adapter required per electrode.

Application: Employ with Series 3E, 3F and 3N electrode fittings in water and noncorrosive liquids at temperatures below 150° F. when (a) the distance from the fitting to the operating elevation exceeds six feet, or (b) the electrodes are to be contained within a metallic tube or pipe of relatively small diameter.

Identification: By the use of a component number which establishes the material of the metal parts. See component number formula.

Material: Choice of yellow brass or 303 stainless steel. The shield is talc filled polypropylene.

Building a control system.

Warrick probe-type level control units range from simple, single-function devices to multiple-function systems with multiple controls, peripheral equipment and motor controls. Systems can be built into a single enclosure of Nema Types 1, 3R, 4, 7 or 12.

Warrick engineers can assist you in evaluating your application and will recommend a system to meet your individual requirements. Generally, control systems progress through the following four levels.

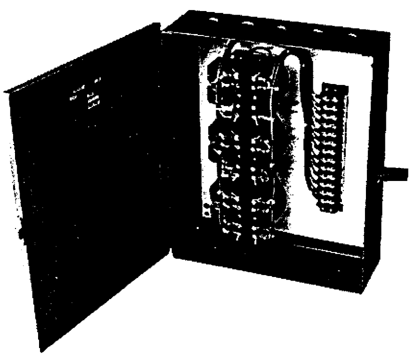
Level I.

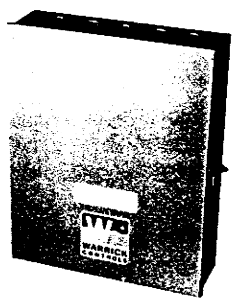
NEMA 1
(5 9/16"H x 5 9/16"W x 3 7/8"D.)

NEMA 4
(6 1/4"H x 6 1/4"W x 4 1/8"D.)

The simplest level control system consists of a single control performing one function. It is installed in an enclosure of appropriate Nema rating.

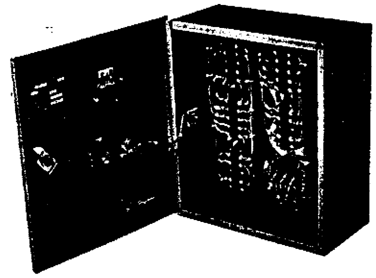
Level II.

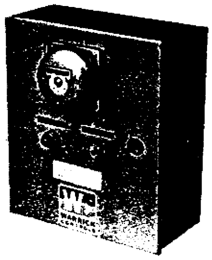




Level II includes multiple controls for multiple functions. A terminal strip for three or more controls is installed in an enclosure of Nema Type 1 through Type 12 rating. Dry contacts are supplied for remote alarms or pump controls.

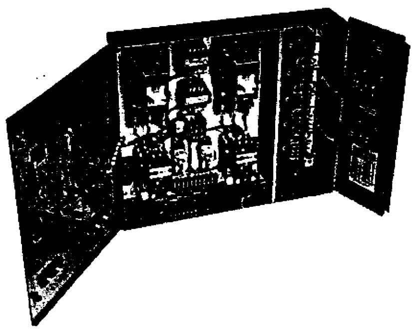
Level III.

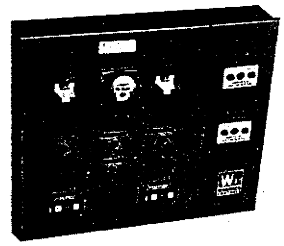




The next level of control involves not only multiple controls to perform multiple functions, but also peripheral equipment such as terminal strips, alternators, indicator lights, selector switches, horns or buzzers. Dry contacts are available for the motor control center.

Level IV.





Level IV control systems perform multiple functions through multiple controls and also include peripheral equipment and motor controls. The addition of complete motor starter/disconnect equipment to peripheral warning indicators means Warrick can be your single source for a level control system. That's important because with only one supplier you have single-source responsibility. With several component suppliers, there's no one to take responsibility for the system.

NEMA Ratings

NEMA-1 General Purpose
NEMA-3R Weatherproof
NEMA-4 Water Tight
NEMA-4X Corrosion Resistant, Water Tight
NEMA-7 Explosion-Proof
NEMA-12 Oil Tight